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Integration of land use and transportation : selection of an appropriate model with Nashville MPO case study

Matthew Stuart Lambert

To the Graduate Council:

I am submitting herewith a thesis written by Matthew Stuart Lambert entitled "Integration of land use and transportation : selection of an appropriate model with Nashville MPO case study." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Planning.

Bruce E. Tonn, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Bruce E. Tonn, Major Professor

We have read this thesis
and recommend its acceptance:

Frederick J. Wegmann

James A. Spencer

Accepted for the Council:

Vice Provost
and Dean of the Graduate Studies

INTEGRATION OF LAND USE AND TRANSPORTATION: SELECTION OF AN APPROPRIATE MODEL WITH NASHVILLE MPO CASE STUDY

A Thesis
Presented for the
Master of Science in
Planning Degree
The University of Tennessee,
Knoxville

Matthew Stuart Lambert
May 2003

Dedication

This thesis is dedicated to my very best friend Aaron Ellison for never letting me quit and always having the faith and encouragement that I needed; my mother, Kathryn Gorenflo, for raising me to be the best that I can be and for always giving me the encouragement to reach my goals; and to my step-father, Louis Gorenflo, for giving me my thirst for knowledge and the mindset for never giving up; and to Nancy Loftis for her ever-present faith and support in me.

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I also thank my best friend Aaron, my mother and father, both step-parents, and the rest of my family. I give a special thank you to my little brother, Christopher for always being you.

Abstract

This study analyzes the information concerning the process of a selection technique for integrated land use/transportation models. The research presents a general history of the integration of the modeling process. It also includes an inventory that describes land use, transportation, and other integrated models. The main focus of this analysis deals with the process of the selection of an appropriate model applied to a specific region or agency. The selection process includes an investigation of what constitutes a good integrated model and the actual selection process itself. This selection process is conceptualized as a matrix table illustrating the method, which allows models to be weighed according to appropriate criteria.

The thesis begins with a brief history of the land use / transportation modeling techniques. Following the history is an overview of some of the current and operational models for the integration process. The main focus of the research follows which entails the selection process of an appropriate model for a specific region. The study answers the question as to what is the best method for selecting a model. The research concludes with an analysis of the selection process for the Nashville Metropolitan Organization case study and their applications.

The study reveals that each agency has to select the appropriate model to best fit their needs. To achieve this, an understanding must first set out to determine what the agency is trying to achieve. This study provides a planning agency or firm with the necessary information to achieve the right selection for their specific requirements.

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Introduction

Introduction and Definition

The process of urban planning has gone through many changes in the past century, and these changes have helped bring better development and design of the world in which we live. With recent advances in computer and information technology, the planning process has seen some of the greatest and most beneficial changes ever. Information technology has allowed planners to model regions to adapt to needs of the planner's and the community.

Only just a few years ago, planners knew that changes in technology were occurring, but before the changes began planners began using modeling techniques to show visually the land use transportation cycle and what cities could look like. These modeling techniques were used especially in the land use planning field; techniques for the transportation field began to arise later.

After the numerical and visual modeling techniques were in practice in planning and transportation, planners began searching about how to integrate the two fields and how such integration would benefit the planning process. Planners raised the question, "What happens to the land use when a road is placed in an area and conversely, how do changes in land use affect roads?" About this time, many models were being placed into the information technology realm by the use of Geographic Information Systems (GIS). This innovation helped planners and the public to visualize the outcome of designs. This innovation also supported the integration of land use and transportation planning, so software developers produced many ways of showing the integration process. Currently, most planners recognize there is a definite need for the integration of land use and transportation planning.

The purpose of this research is to identify the major integrated land use / transportation models now available for general use and demonstrate a process for selection of a model for application in a specific city. Nashville, TN is used as a case study for the demonstration. The study reviews the basic modeling techniques for land use and transportation planning and, by giving an overview and details, will offer a better understanding of what is available. A brief history of how modeling techniques have become available to the planners is described. Literature is reviewed on the need for the integration and what is currently available.

After the general discussion of research, a case study is presented to demonstrate an application of the research. The case study shows how the Nashville Metropolitan Planning Organization (MPO) can use the decision making process introduced here to find a modeling technique that will show the integration of land use and transportation according to their present and future needs for the five county region which includes Davidson, Rutherford, Sumner, Wilson, and Williamson, TN.

Information technology has dramatically improved the capabilities for modeling planning for visual simulation. This research will provide an understanding of the available models and a method for the decision making process for choosing a model. Integrated models provide planners with vital/useful tools in efforts to achieve a more ideal functional society.

Significance of Study

The research presented here helps planners, architects, design firms, and governmental agencies to understand the need for the integration of land use and transportation planning. It also helps them make the necessary decisions on which modeling technique best meets their needs. Planners are given information to make the modeling simulations and techniques that are available work for them and to decide upon the right one for them. Planners are made familiar with the software presently available to model this interface.

Most planners realize of the need for integration of the modeling process. A good statement is presented by Southworth to show the need for the integration to achieve good comprehensive planning:

"Transportation planning must bring together an understanding of (1) how the transportation sector operates, (2) how traffic-generating and attracting land is developed, (3) how other technologies affect the demands for travel, (4) how modern companies make their siting and site relocation decisions, and (5) how the modern industrial lifestyles of today's households affect, and are in turn affected, each of the above." (Southworth, 1995)

The case study is significant because it can aid the Nashville MPO in the decision-making process of models that integrate land use and transportation and the impacts each has. The case study illustrates to all planners the importance of integrating land use and transportation simulations. Finally, this research suggests how analytical models might be improved to achieve the most accurate and efficient simulations for the integration possible, so that planners can use advancing technologies "to better serve and protect" the public.

Methodology

The research methodology will present the information that is available and then make an analysis of what can be done in efforts to help with the decision making process. This research begins with an examination of the history of existing land use models and then moves to the transportation models. After those are presented, a history of the development of integration process is given.

This research discusses how the integrated models are developed and gives an overview of current models. Some models are selected for a detailed overview, due to their use of GIS-based software to show modeling simulations visually. This approach allows a comprehensive overview of the techniques that are currently available and their positive and negative aspects for the planning process.

The main focus of this research is the decision making process for the selection of the appropriate modeling technique or simulation for a specific region by a public agency or private firm. Accordingly, the study presents the best way to decide on the method and presents it by using the Nashville MPO as a case study.

Regarding the method for the decision making process a matrix is presented to show the benefits of using various methods. The study shows that the decision matrix is the best method for the decision-making.

The decision matrix is designed as a basic method that allows planners to use their own criteria and specific models that can be applied. The planners then can give their own weights to the criteria and give a score. The scores then can be tabulated and used to select the best model. This study shows that the matrix is by far the best method for the decision on how to choose the appropriate modeling technique for the integration of land use and transportation. Accordingly, the decision matrix will be applied to the case study to illustrate the outcome of the decision making process.

Case Study Methodology

The case study methodology is based on the outcome of the best method for the decision. To some degree, the Nashville MPO is governing the method in their effort to produce the results that they want to achieve and can afford. Through consultation with them, an understanding of what is desired has been determined and expanded upon. This consultation has helped them to recognize more clearly than before the presently available information.

This research details several currently available programs to model land use effects on transportation and vice versa. To achieve a result that can be presented to the Nashville MPO, a decision matrix is designed and tested as thoroughly and as accurately as possible. Each of the types of models is evaluated using a set of questions regarding capability, cost, and efficiency. These in turn are given scientifically researched 'best guess' scores. Each of the scores is justified with reasons and definitions. This process allows the results to be tabulated, thereby obtaining an appropriate model for MPO selection.

Seven models are evaluated to determine the most efficient for the Nashville MPO. The models are divided into two groups; 'Regional – No Travel' models and

'Regional – Travel' models. The Regional – No Travel models deals with models that have do not incorporate a travel demand forecast in the modeling, while the Regional – Travel models do include a travel demand forecast. The No Travel models include LUCI, What If, Spreadsheet-Manual Delphi, and INDEX (Forecasting). The travel models include UrbanSims, ULAM, and CorPlan.

Once the research has found the most appropriate model for the use of the MPO, actual selection of the model is left to the organization's discretion. It is hoped that the research process provide substantial aid and will assist in the better planning and design for the region that the Nashville MPO encompasses.

Methodology Summary

Dr. Fred Wegman and Mr. Jerry Everett have aided the researcher in determining the best course of action for the decision making process. These two have been instrumental in defining of a land use transportation model and evaluation of alternative models for the Nashville MPO case study. The Nashville MPO department has also helped in selecting and conducting independent approval for deciding the weights for the criteria and provided some specific models to look at that they might consider.

This research reviews briefly the history of how the integration of land use and transportation modeling arose. It also gives a basic overview of the models that are currently available to show this integration. Finally, the study generates a plan for the best course of action on how to decide on the best model for specific planners and their regions. This study covers the basic uses and also includes the case study for Nashville MPO and its impacts on the land use and transportation.

Chapter 2

Literature Review

Several articles are reviewed below to present a better understanding of the importance of the interface between land use and transportation. The complete literature review is included in the research.

Frank Southworth's article "A Technical Review of Urban Land Use—Transportation Models as Tools for Evaluating Vehicle Travel Reduction Strategies," reviews some of the different models currently available to simulate the combination of transit and land use planning. Southworth presented this report to Office of Environmental Analysis, Sustainable Development, and the U.S. Department of Energy. This report is useful to the study insofar as it presents available modes of transportation modeling and how they may be applied.

In regard to the Nashville MPO, the report is particularly relevant as it pertains to growth, the main research concern. According to the review, "experts expect urban travel to continue to increase as a result of (1) significant population gains within our largest cities, (2) a generally growing interest in discretionary forms of non-work travel, and (3) our continued failure to develop alternatives to low occupancy vehicle use." (Southworth, 1995) The report includes significant amounts of detailed information on how the models work and the formulas devised to work the models. This report presents a thorough understanding of some current models, in 1995, used to facilitate the land use and transportation integration.

Another useful report is Paul Waddell's "Analytical Tools for Land Use, Transportation, and Growth Management." This report gives an overview of some of the tools available to model integration, but focuses primarily on the UrbanSim model. UrbanSim is thoroughly explained to give a better understanding of its inner workings.

Waddell's review of modeling tools entails an analysis of the requirements for the planning context, that is, of what is needed for the development of new models to link land use and transportation issues. Waddell was instrumental in the development of UrbanSim. The requirements include the ability to "represent local markets, represent local governmental decisions, represent environmental constraints, represent high level of geographic detail, facilitate public participation, develop flexible and open software, facilitate visualization and evaluation of results, analyze regional effects of transportation on land use, facilitate complex policy evaluation processes, and analyze urban development as dynamic process." (Waddell, 2002) These are very beneficial to all practitioners, especially those involved in designing modeling software. The report is well developed and organized to provide substantial detail on the UrbanSim Model, but it lacks in the evaluation of the other models.

An additional report on modeling tools is the "Review of Land Use Models: Theory and Application," by Kazem Oryani. The review is a good overview of the history of land use models and how they may be applied. Oryani provides an inventory of types of models and then concludes with a methodology for selecting an appropriate land use model. This report was written to provide a recommendation for an applied model for the Delaware Valley Regional Planning Commission. Oryani asserts that DRAM-EMPAL, which is the most commonly used model, is the only model that can allow for the integration of land use and transportation planning. (Oryani, 1999) Oryani recognizes the desired attributes for the selection process. This paper is helpful in showing the selection process for a land use model. However, it neglects the issue of the integration of land use and transportation.

Whit Blanton's report entitled "Integrating Land Use and Transportation," deals with integration on a level of mobility and accessibility focusing on the University of Florida in Gainesville. This university is beginning to rethink its approach to transportation planning in integrated terms. The main purpose of the paper is to show "how planners are geared towards mobility and how we have ignored livability and community." (Blanton, 2000) Blanton shows the need for the integration when he states:

> Too often, quality of life or "livability" concerns are only considered as a reactionary response when neighborhood groups protest a proposed transportation project. Until our planning process for land use and transportation are more integrated, we can expect more of the same. (Blanton, 2000)

This report shows how the integration process can lead to reduced vehicle miles traveled and improvements in air quality, not to mention a more visually-appealing landscape. (Blanton, 2000) Blanton also points out that there is a need for performance measures to guide in the selection process. This is by far the most useful characteristic of the paper. The report is complete and thorough in showing the need for the integration of land use and transportation. Unfortunately, it is lacking insofar as it is geared for the University of Florida and not for the overall perspective of all communities. However, it does give an understanding of what is needed for the Nashville project.

The report, "Guidance for Land Use Impacts of Transportation" by Samuel Seskin is a guidebook providing information to agencies to help with the integration process. This report is a summary of the NCHRP 8-32 (which is the National Cooperative

Highway Research Program report titled "Developing and Maintaining Partnerships for Multimodal Transportation Planning") and use-guidelines published by state departments of transportation. The paper is weakened by the omission details needed for the use of both transportation and land use planning that are given in the guidebook. Overall, Seskin provides a brief overview of what the guidebook states, but leaves out specifics on the information needed to achieve the planning combination. (Seskin, 1999)

Another source of information for the integration of land use and transportation needs is a chapter from the web guide "Transport Geography on the Net," by Jean Paul Rodique. Chapter Six, entitled "Transportation / Land Use Modeling," describes types, stages, requirements, and a listing of major models. The chapter is very brief yet very thorough in achieving the goals desired.

Rodrigue presents a very clear definition of what a model does when he states: "it is used to represent and process relationships between a set of concepts, ideas, and beliefs." (Rodrigue, 2002) The chapter examines the four stages of the land use / transportation model, including trip generation, trip distribution, modal split, and spatial patterns of movement. The most important aspect of the whole integration process, the "origin destination data" is also described. Rodrigue presents the reader with the necessary basic information for the design of land use / transportation models and shows the importance of integrated models in the design process. The chapter is good and concise and allows the reader to understand the workings of the models and their significance without an over whelming amount of technical data.

The final report reviewed is "TCRP Report 48 – Integrated Urban Models for Simulation of Transit and Land Use Policies: Guidelines for Implementation and Use," by Eric Miller. The National Transportation Research Board puts out this report in order to show the information needed to achieve integration. Additionally, this report provides planners and engineers with the information needed to implement and use a variety of model techniques including a review of land use transportation models available. Miller reaches three important conclusions that allow the reader to better understand the significance of the integration:

> All currently operational models fall short of the ideal model to varying extents, at the same time, current models individually and collectively display many strengths and generally provide a solid basis for further evolutionary improvements, and despite the potential for significant evolutionary development of existing models will need to be developed in order to fully achieve the ideal model. (Miller, 1999)

This report is very explicit about the guidelines for the selection of models to allow for the integration of land use and transit. Miller is effective in presenting planners with previously lacking information to assist in the planning process.

The literature that has been presented shows the need for the integrated models and gives some information on the specifics of some models. The literature to date has not thoroughly detailed the information needed to select a specific model for any region. This is the part that is lacking in the land use transportation modeling field today. The selection of an appropriate model is what this study is trying to represent. The research has presented the literature that is available on the needs for integration and some details of certain models. This research will continue on to describe the background of the integration of land use and transportation models.

Chapter 3

History of the Integration Land Use and Transportation Models

The integration process of land use and transportation can be traced back to ancient times when cities were just beginning to take shape. Land-use and transportation planning has been the result of many social, economical, and technological advances through our history. Today, the complexity of models and simulations for achieving this process make it hard for most to decipher.

Land use planning began as cities were starting to take shape and people began to take an interest in choosing the best-suited places for specific land-uses. Actual planning processes were first formulated at the turn of the twentieth century with the development of planning agencies. The new focus in planning was a result of cities' rapid growth and overcrowding. Planning since then has continued to grow in significance and form the cities that we live in today.

Transportation planning could technically be traced back to the same times as land use planning. During the time of the beginning of land use planning, people were traveling by foot or horse to get to their destinations. Scientifically speaking, transportation planning started with the industrial revolution and the invention of the engine, which brought forth trolleys, trains, and most importantly, the automobile.

The automobile was by far the most important influence in the twentieth century on the transportation planning process. During the early part of the twentieth century, there was a rise in actual planning for transportation, but the system of transportation really took off during the middle part of the century, in with the development of the interstate system and the 1962 Federal Aid Act requiring the three C's planning process (Continuing, Coordinating, Comprehenisive). Transportation planners have a common goal, which is the fact they are developing and designing networks to move people efficiently.

During the middle part of the twentieth century, with the invention of computers came the development of numeric modeling techniques that could be used by planners. These techniques were very basic in that they were able to perform basic calculations to show forecasts.

The integration of land use and transportation planning came about with an understanding of what happened to the land surrounding transportation systems, but also what transportation resources people in certain land uses needed to get to their destinations. The integration of land use planning and transportation planning showed that certain land uses needed certain types of transportation systems and vice versa. According to a report by Rosenbaum for the Environmental Protection Agency, "the rapid increase in vehicle miles traveled in the last 50 years (and the resulting increase in emissions from transportation sources) has accompanied land use development patterns that rely on the automobile as the primary means of transportation." (Rosenbaum, 1997)

The actual modeling of the planning process can be dated back to the 1960's, during the time of the great surge in mainframe technology. According to the U.S Department of Transportation, the modeling process began with the Lowry Model. The article states, "modeling urban form, as represented by location (land use) models, was primarily conceived by Lowry in his Model of Metropolis (1964). This model is based on the assumption that ...the place of employment determines the place of residence."

(Harris, B., 1996) Lowry was the first to apply the "gravity model" to residential locations. (Harris, B., 1996)

Other models were soon developed to solve problems in the Lowry Model. In the figure following (Figure 3.1), from an article that deals with a review of land use models, a short chronological history of urban models is given to show how today's models emerged, which also shows the development of economic type models and gravity type models. Models began developing very rapidly, each one claiming to be a better method for the transportation planning process.

The land use and transportation integration modeling process began around the 1970's. During this time, models showed the indirect land use effects of transportation projects. Planners learned that to represent this relationship properly, integrated models are required. (Louis Berger Group, 2002) According to Harris, "Stephen Putnam deserves recognition as the first clearly to emphasize in publications the importance of the integration." (Harris, 1996)

A major influence on the integration process was the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). According to the Transit Cooperative Research Program (TCRP) Report – 48, ISTEA "required metropolitan and statewide transportation plans to be integrated with land use plans." (Miller, 1999) After ISTEA came the Transportation Equity Act for the 21st Century (TEA-21). This act also established the requirement for integration but did so in a broader language than ISTEA. Both acts left the method for achieving this integration to the Metropolitan Planning Organizations (MPO) and State DOTs.

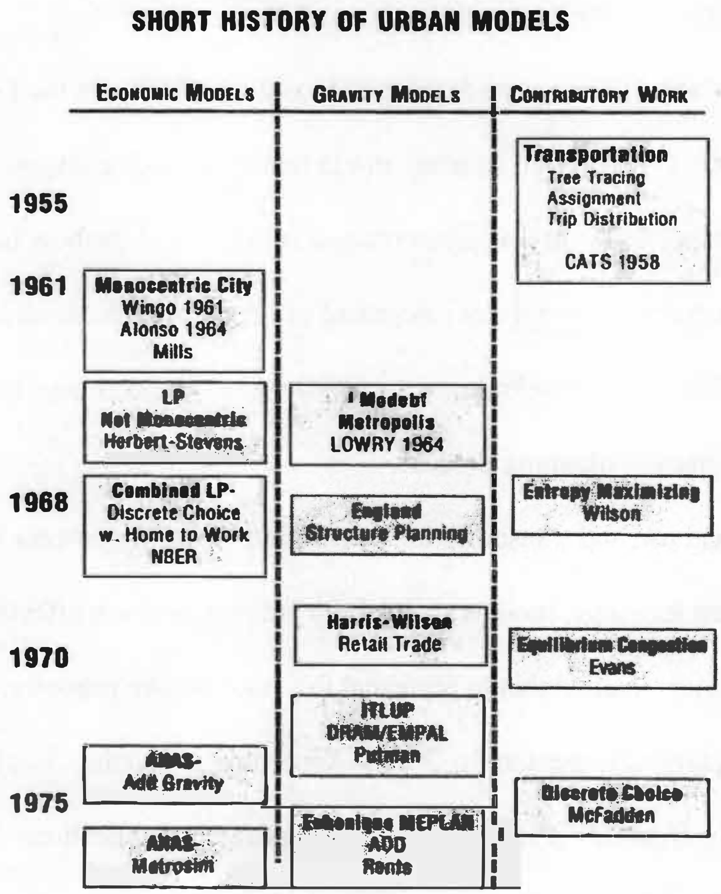

Figure 3.1 History of Urban Models.

Source: Oryani; 1999; *Review of Land Use Models: Theory and Application.*

A major invention in software drastically changed the modeling field: the software called Geographic Information Systems (GIS). GIS is able to show data input and output visually on maps. Models transferred into GIS could show the effects of land use changes visually, thus speeding up the modeling process drastically.

After the GIS software began to take off in the 1990's, many new software companies started making packages that modeled land use and transportation planning based on GIS. The new packages were able to show a simulation of what could occur in the future in a specific area or region. The current plethora of modeling technologies brings us the dilemma that we are faced with now: how do we as planners decide which model is best for us to show the necessary integration of land use and transportation?

So here we have seen that land use and transportation planning has been around for centuries, in basic terms. Based on transportation planning needs and utilizing 1962 Federal Aid Act requiring a 3'C planning process in all urban areas of a population 50,000, modeling techniques were developed to help with the planning process and were designed based upon the social, economical, and technological advances through history. At present, we have many ways to model our need for the integration of land use and transportation planning, but no easy answer to the question of which is best for a particular area. The model selected must reflect the issue of concern, staff resources, and means of communicating results.

Chapter 4

Inventory

Introduction

Currently many types of models for planning exist. Some models deal with land use aspects individually, while others deal with travel demand aspects individually. Comparatively, some models are used to deal with the integration of both of these models. This section reviews some of the basic models that have been used for these aspects and points to those that are presently available. To understand fully what an integrated land use and transportation model is one must understand each of the different types of models associated.

Land Use Model Inventory

Since the beginning of forecasting land use changes, land use models have always been used to show the best decision for what to place in a specific area. Land use models have been developed for specific places or regions and general applications. Some of the models are very basic, and some are detailed to the point that they can show visual simulations. Some models are very user-friendly while others are so complex and require so much data input and calculations that it takes trained experts to run them efficiently.

One of the most basic models is the scenario model or the "best guess" model. This model takes a "What If" approach, in that it asks the question "If this is built, what will happen in the future?" This model can create many problems if not given the most scientific basis for decisions.

Another model that is very common in the planning field is the basic gravity model. This model shows the general characteristics of forecasting for a single aspect of the planning field. The basic gravity model is used to predict movement of people, information, and commodities between cities and even continents taking into account the population size of two places and their distance. This model is a good basis for prediction, but lacks any theoretical basis. Many basic gravity models would have to be completed to get a thorough forecast for the planning field. The Lowry model applies the gravity method model to residential locations. The Lowry model is based on the principle that regional and urban growth (or decline) is a function of the expansion (or contraction) of the basic economic sector, having impacts on two other sectors, retail and residential. The model aims to establish a representation of the residential structure, of employment and of services in an urban area

The traditional Trend – Delphi approach, by far one of the most common methods of forecasting is another basic modeling technique focusing primarily on the land use field. The technique used is to obtain and refine opinions of a group of experts. In this approach, according to the Transportation Research Record 1805, by Sonny Conder, "any attempt at comprehensive modeling was abandoned and a combination of trend projections was adopted, informed by both a land use inventory of developed and vacant lands and panels of local technical specialists and various interest groups representing developers, local jurisdictions, and environmentalists." (Conder, 1995) The Trend – Delphi approach places "knowledgeable" people together and lets them make decisions based on trend projections only.

Many more models have been developed to meet the needs of specific regions. Most of these are listed in the table below that was developed from the article by Kazem Oryani, "Review of Land Use Models: Theory and Application." Many of the models listed in the table are not available commercially for agency use. Available models include TOPAZ, MEPLAN, ITLUP, TRANUS, TRACKS, and TRANSTEP.

The first table (Table 4.1) shows some of the Land Use models and their countries of origin. The following list (Table 4.2) is a complete updating from the article by Oryani that gives models that are identified as being currently operational. Some of these models are specific to their region while some can be used more broadly.

Table 4.1
Land Use Models Inventory

Model	Country
TOPAZ	Australia
MEP	U.K.
ITLUP (DRAM-EMPAL	U.S.A
LILT	U.K.
AMERSFOORT	Netherlands
CALUTAS	Japan
IRPUD (Dortmond)	Sweden
OSAKA	Japan
SASLOC	Sweden
MEPLAN	U.K.
TRANUS	Venezuela
TRACKS	Australia
TRANSTEP	Australia
TOPMET	Australia

Source: Oryani; 1999; *Review of Land Use Models: Theory and Application*

Table 4.2
Currently Operational Land Use Models

Acronym	Model Name
POLIS	Projective Optimization Land Use Information System
CUFM	California Urban Future Model
BOYCE	Models developed by Boyce
KIM	Model developed by Kim
HUDS	Harvard Urban Development Simulation
IRPUD	Dortmund model developed by Wegener
RURBAN	Ransom Utility Model

Source: Oryani; 1999; *Review of Land Use Models: Theory and Application*

Various limitations hinder the resulting projections for land use models. According to the report by the EPA, there are two main land use limitations: "1. Representation of polycentric urban development and 2. Non-transportation factors for specific business siting." (Rosenbaum, 1997) The greatest limitation is that most of the models do not include the travel demand portion.

The presentation of land use models above gives an overview of some available models and some that are not. Land use models have been designed for specific regions while some have been designed to be used anywhere. The above has introduced some of the land use models that are currently available to MPOs and other private planning firms.

Travel Demand Model Inventory

Many different models give forecasts for the travel demands or transportation aspects of land use planning. The models are basically designed by the same guidelines. Some of the more recent models have been developed using modeling software packages.

Models like the origin-destination and the gravity model are based upon transportation forecasting. Models like these are still the basis for modeling transportation and travel demand today. Transportation models are typically similar in their formulation of the transportation process into four steps: trip generation, trip distribution, modal choice, and trip assignment. This traditional model can be seen in the figure following (Figure 4.1).

A few software packages are available for transportation modeling, such as TRANPLAN, EMME/2, TransCAD, QRS II (Quick Response System II), and MINUTP. These computer models, according to the EPA report, "are workstation versions of the Federal Highway Administration's Urban Transportation Planning System (UTPS) model." (Rosenbaum, 1997) The software allows the user to forecast the transportation needs more accurately and with quicker speed than traditional methods.

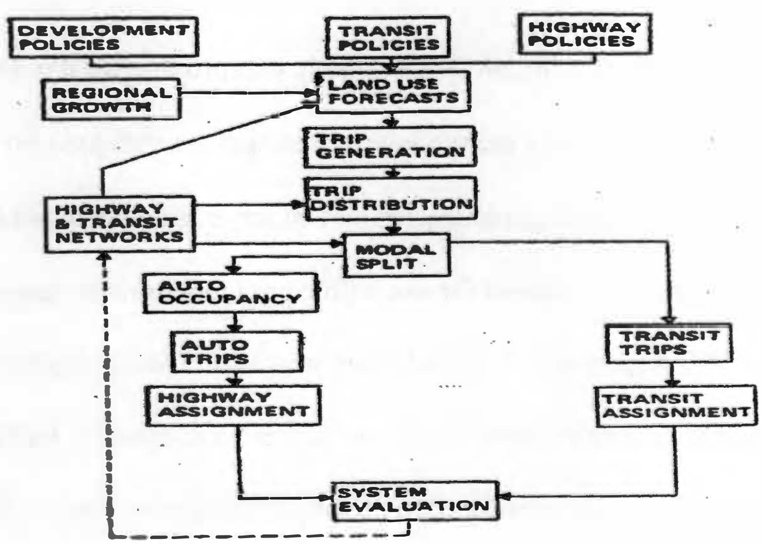

Figure 4.1 Four-Step Travel Demand Model.

Source: Rodrique; 2002; *Transportation / Land Use Modeling*

Like the land use models, the transportation and travel demand models also have limitations. Some of the limitations described by Rosenbaum include "lack of feedback of travel impedance to trip generation, omission of trip changing behavior, omission of temporal choice behavior, omission of non-motorized travel modes, and insufficient attention to urban freight." (Rosenbaum, 1997) These limitations show that, to provide for a better model for a region, the travel demand models will not work alone.

The above discussion has shown that travel demand or transportation models are available to forecast the future, but do not allow for a thorough model for a specific region. Also, the travel demand models typically follow a standard set of guidelines or processes to achieve the model. Some of the models currently available such as TransCAD have elements to represent models' inputs and outputs visually.

Integrated Inventory

There are currently many models available that provide for the integration of land use and transportation. Some of the models are based on or designed for specific areas, while others can be used more generally for almost any region. Most of the models today are converting to or being designed for use with computers or more specifically GIS.

The NCHRP Report 423A, "Land Use Impacts of Transportation: A Guidebook," gives a very detailed listing of some of the formal land use models. Each one of the models goes through a series of informative aspects that details each of the working of the models. The aspects deal with the requirements for use, how it works, and applications for each model. The models detailed include DRAM/EMPAL, MEPLAN,

TRANUS, METROSIM, HLFM II+, LUTRIM, CUF, and UrbanSim. This is a very good resource in understanding some of the basic models that are out there. (Transportation Research Board, 1999)

To gain a better comprehension of the integrated models, Dr. Jean-Paul Rodrique wrote a report on the types of models and begins with some basic information. He states that "there exist four levels of complexity of modeling transportation / land use relationships." The first, static modeling is generally the measure of accessibility. Next, system modeling conveys the behavior of a system within a given set of relationship variables. The third is the modeling interactions between variables that integrate several models to form a system. Finally is modeling in a decision-taking environment, which implies the application of the integrated model and also the analysis of its results. (Rodrique, 2001)

Many models currently exist, most of them developed during the 1960s and 1970s, but the best known are the Lowry model, ITLUP, and MEPLAN by Marcial Echenique. According to Dr. Rodrique, the Lowry model "links two spatial interaction functions represented as the location of industrial employees and the location of service employees." (Rodrique, 2001) The ITLUP model is composed of three parts: DRAM (Disaggregated Residential Allocation Model), EMPAL (Employment Allocation Model), and travel demand. This model is a derivative of the Lowry model. Another derivative of the Lowry model is the MEPLAN model. This model considers more comprehensively the housing market and its influence on the location of the population. The figure following (Figure 4.2) shows the linkages of DRAM-EMPAL, MEPLAN, and METROSIM.

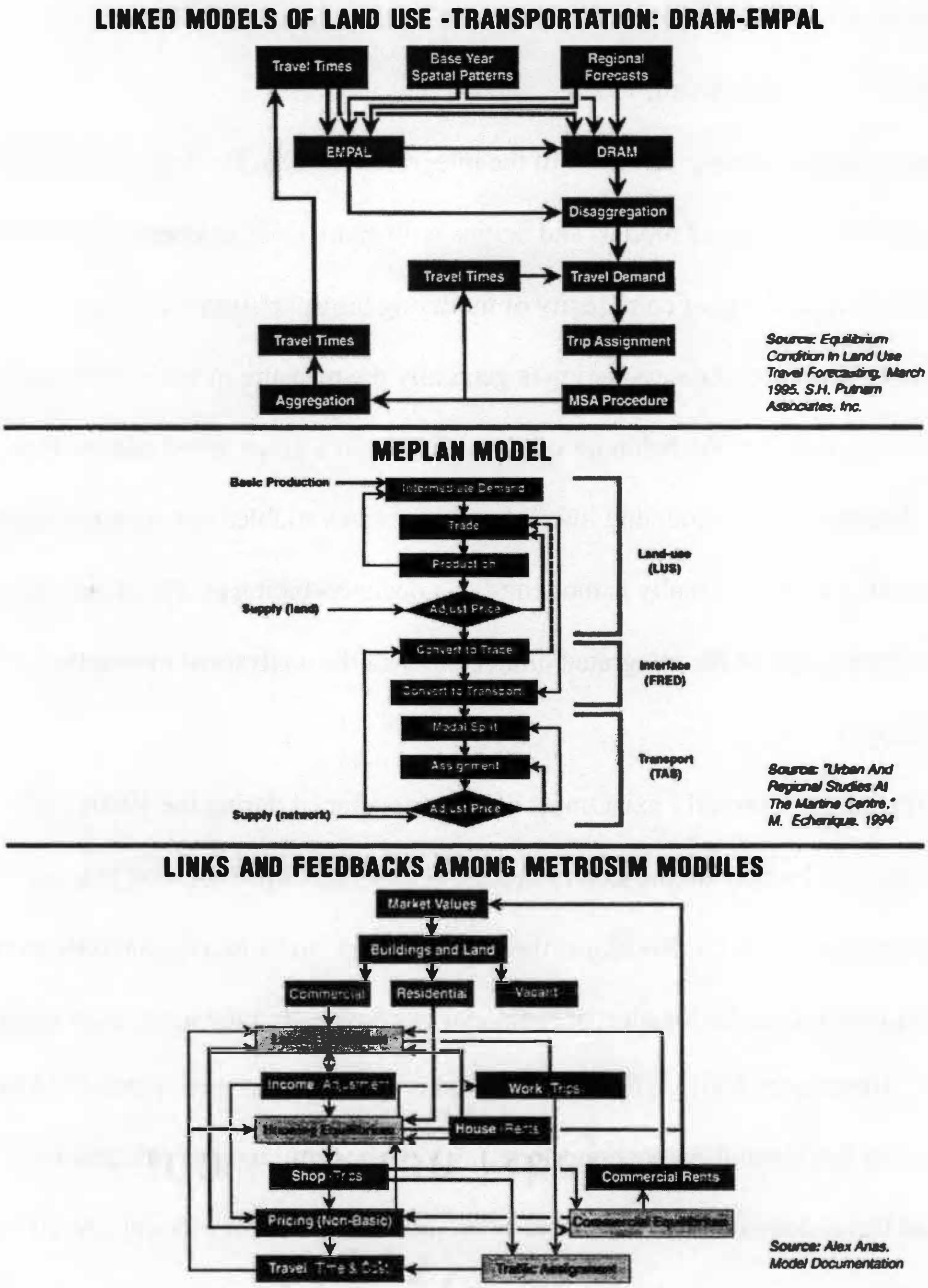

Figure 4.2 Linkages Between Some Models

Source: Oryani; 1999; *Review of Land Use Models: Theory and Application*

Another of the most common integrated models is TRANUS, developed by Tomas de la Barra. TRANUS is similar to the MEPLAN model, but it differs slightly in that TRANUS makes greater use of "logit-based" formulations (which is the ratio and frequency for two mutually exclusive outcomes) for mode and route choice.

The Land Use / Transportation Impact Model (LUTRIM) model was developed by William Mann specifically to determine land use impacts due to transportation improvements. The figure following (Figure 4.3) shows the major steps within LUTRIM and how it works. Alex Anas developed a model, METROSIM, which takes an economic market-based approach to residential and employment location. The third figure (Figure 4.4) is a very detailed matrix that shows a comparison for some of the major integrated models and provides the theory on which the model is based, the data required, the sector modeled, and the cost for implementation.

According to the TCRP Report – 48 "there are three other models of interest: MUSSA, NYMTCLUM, and UrbanSim developed by Paul Waddell. These are noteworthy for two main reasons; each is operational or sufficiently close to being operational and each contains a significant market representation." (Miller, 1999) Some of the others include LUTRAQ (Land Use / Transportation and Air Quality), Place3s, Urban Growth Simulator (by Kent State University), INDEX, ULAM (Urban Land Allocation Model), and the CorPlan Model. These last three models will be discussed in detail in the case study for the Nashville MPO. Appendix E & F show two more comparison charts of models and their applications and structure from other sources.

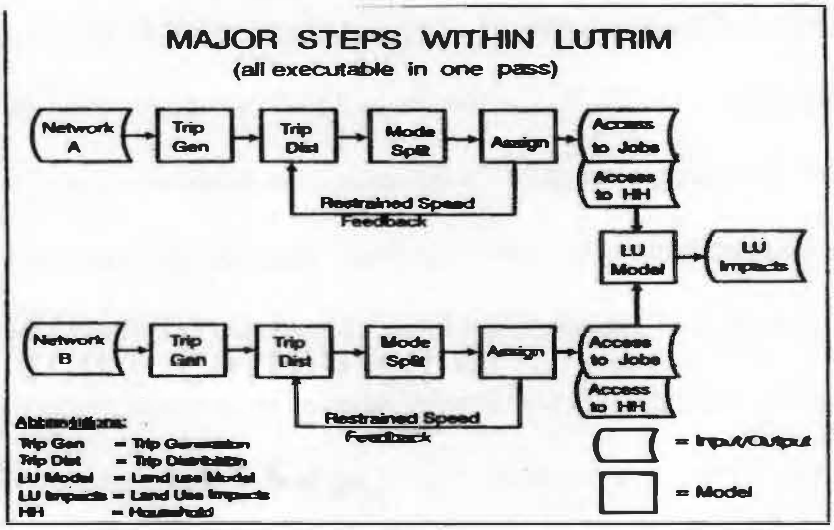

Figure 4.3 Major Steps Within LUTRIM

Source: Mann; 1999; *Land Use / Transportation Impact Model-LUTRIM*

Model	Model Theory	Sectors Modeled	Policies Modeled	Data Required	Level of Aggregation	Platform	Implementation
ITLUP (DRAM/ EMPAL)	Lowry formulation random utility network equilibrium	employment population housing land use travel	land use regulations transportation improvements	employment by industry households by income quartile total land area land area by use category vacant developable land travel cost matrix	TAZs or higher level of aggregation	DOS Windows Unix	$15K -$100K complete consulting contract package 2-person plus planning team
MEPLAN	Lowry formulation random utility network equilibrium land use equilibrium	employment population housing land use travel networks workplaces goods transport	land use regulations transportation improvements transportation cost changes	land use and price by sector floor space and price by sector population (by household type) employment by sector input-output tables forecast of basic employment transportation network by mode	Groupings of TAZs	DOS Windows Unix	$40K complete licensing consulting for implementation/calibration available planner, engineer, economist team
TRANUS	Lowry formulation random utility network equilibrium land use equilibrium	employment population housing land use travel networks workplaces goods transport	land use regulations transportation improvements transportation cost changes	land use and price by sector floor space and price by sector population (by household type) employment by sector input-output tables forecast of basic employment transportation network by mode	Groupings of TAZs	Windows	$6K complete licensing consulting for implementation/calibration available planner, engineer, economist team
METROSIM	random utility general equilibrium	employment population housing land use travel networks workplaces	transportation improvements	Census Transportation Planning Package (CTTP) transportation network by mode data on real estate values	TAZs or higher level of aggregation	Unix	licensing by arrangement consulting for implementation/calibration required team size varies
UrbanSim	Lowry formulation random utility locational surplus land use equilibrium	employment population housing land use travel workplaces	land use regulations transportation improvements	regional control totals for population and employment households (STF3 and PUMS) parcel land use (GIS) land use regulations (GIS) infrastructure plans (GIS) environmental constraints (GIS) regional development costs government regulations travel cost matrix	TAZs or higher level of aggregation	DOS Windows MacOS Unix (Java Developers Kit)	no cost for downloadable software or documentation consulting not required for use team size varies, must include GIS expertise

Figure 4.4 Comparison Chart of Major Integrated Models

Source: Louis Berger Group; 2002; *NCHRP Report 466*

Chris Porter completed a survey in 1995 to survey MPOs of the 35 largest U.S. metropolitan areas and learned what type of integrated models they were using for the transportation planning process. This survey established that:

- Twelve MPOs are using DRAM-EMPAL models
- Five MPOs are using their own models (POLIS, PLUM, and three local models)
- One MPO is in the process of creating its own model
- Two MPOs use the Delphi (exchange of expert opinion) Technique
- Fifteen MPOs do not use land use models but use qualitative procedures. (Porter, 1995)

As seen above, many types of integrated models are presently available; the field will continue to grow with advances in technology and urban growth. Some models are being produced to meet the needs of specific regions or agencies, while others are being designed in effort to aid all regions. It is hard to predict where the integrated models will lead us in the future.

Summary

Planners have a need to use models to show what is likely to occur in the future by means of numbers, graphs, and other visual aides. Models have been designed in the planning field to include land use aspects or travel demand (transportation) aspects. Recently, models have taken an integrated approach to show how the two are related.

This chapter has provided lists and descriptions of many of the types of models that are currently available and demonstrated how some models have been used as a basis for others. The models have been categorized into land use types, transportation types, and types that integrate the two aspects of planning. Presently, many models exist to show planners how to forecast. The question that remains to be answered is how to pick a specific model.

Some of the models will be given further discussion in coming chapters.

Chapter 5

Model Selection Techniques

Introduction

Renewed interest in integrating land use and transportation planning has again come together recently because planners have realized that there exists a very powerful relationship between the two. This relationship has led to an improved integration of land use and transportation modeling. This chapter shows the relationship that exists between transportation and land use, and describes what it takes to apply a good integrated model. The chapter concludes by explaining a means for selecting an appropriate model for a specific region.

Existing Relationships

A good integrated model can be ultimately defined as the one that seems best or the one that is used the most, right? Wrong! A good model has many components to lead the planners in the right directions to give the best-integrated forecasts possible. Many believe they have designed the best model currently available until the next one comes along and tops that one. Some standards do exist for the integration of land use and transportation models.

The fundamental standard that all must understand is that the integration process is a never-ending cycle. The figure following (Figure 5.1) shows the transportation – land use cycle and how the relationship is joined. Dr. Jean-Paul Rodrique presents a figure (Figure 5.2) to show the spatial relationship of the components of the

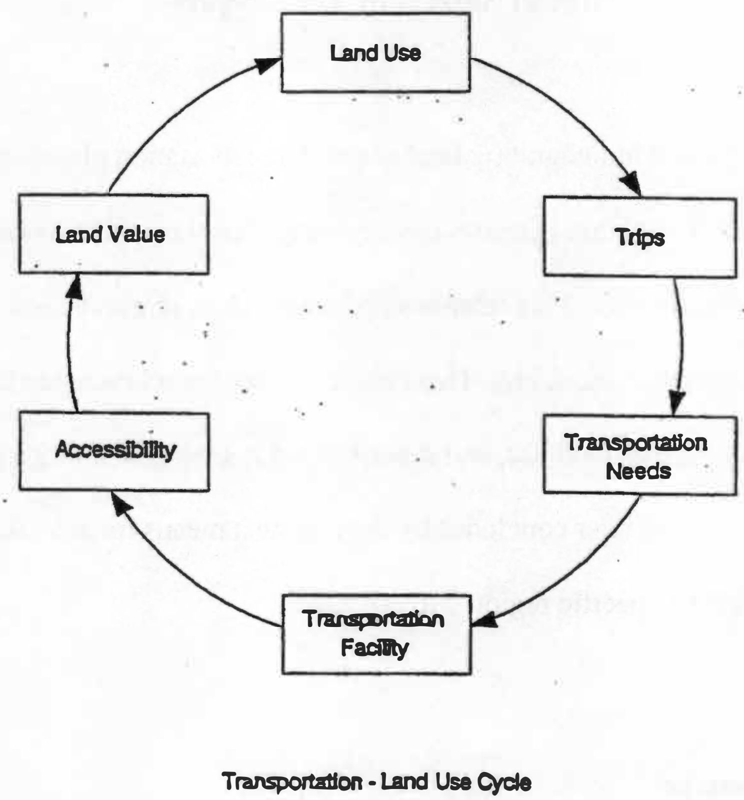

Figure 5.1 Transportation – Land Use Cycle

Source: Seskin; 1999; *Guidance for Land Use Impacts of Transportation*

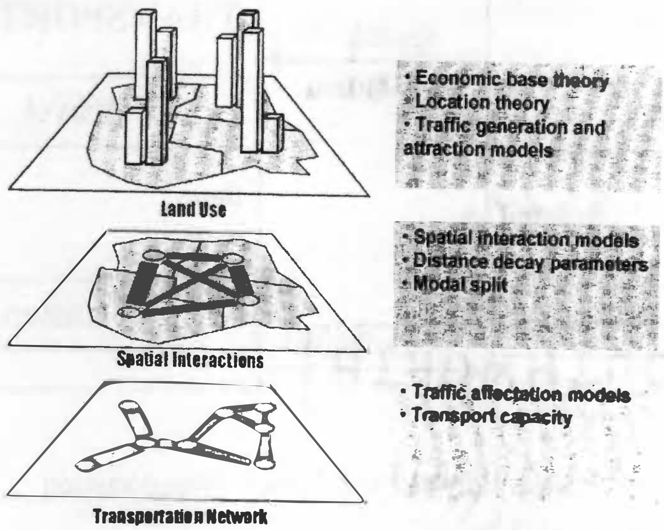

Figure 5.2 Components of a Transportation / Land Use system

Source: Rodrique; 2002; *Transportation / Land Use Modeling*

transportation / land use system. (Rodrique, 2001) Another figure (Figure 5.3) from the EPA report by Rosenbaum also shows the potential links between the two, giving a more detailed perspective of the cycle.

Today, a planner cannot recommend a network of roads without considering the impact on the land use and cannot place a certain land use somewhere without affecting the transportation network. The following two figures show linking relationships as conceptualized by Frank Southworth. The first figure (Figure 5.4) shows the relationship between land use and transportation. The second figure (Figure 5.5) shows the complexity of functional linkages in urban system dynamics.

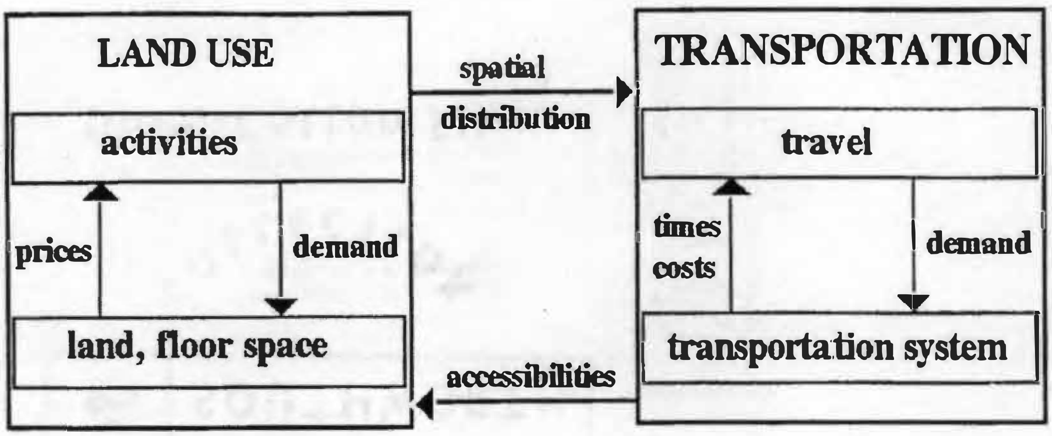

Figure 5.3 Links Between Land Use / Transportation

Source: Rosenbaum; 1997; Evaluation *of Modeling Tools for Assessing Land Use Policies and Strategies.*

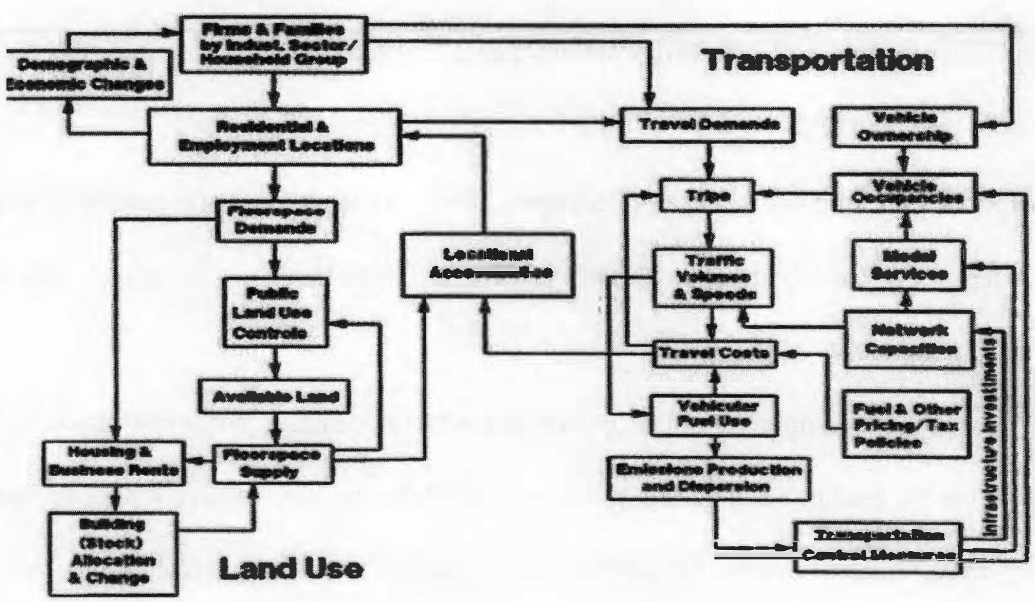

Figure 5.4 Transportation / Land Use Linkages

Source: Southworth; 1995; *A Technical Review of Urban Land Use Models.*

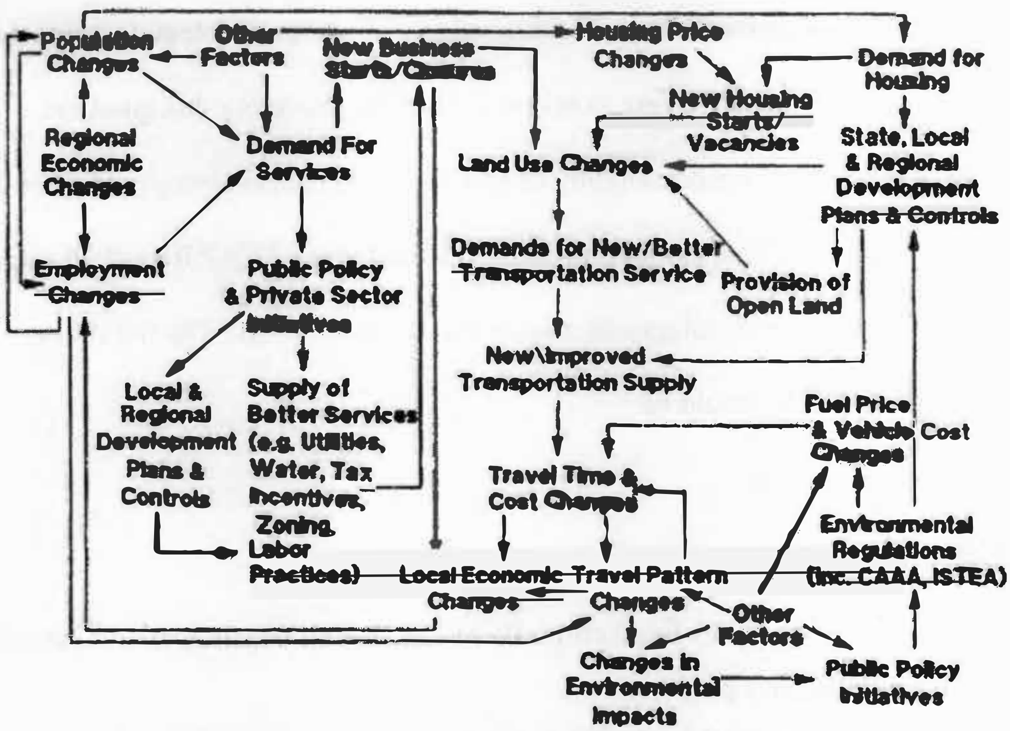

Figure 5.5 Complexities of Functional Linkages in Urban System Dynamics

Source: Southworth; 1995; *A Technical Review of Urban Land Use.*

What makes a Good Integrated Model

One of the basic principles for deciding what makes a good integrated model is to focus on what the planners are trying to achieve. By first answering this question, planners are able to gain an understanding of how to obtain the necessary model for the integration process. The Transportation Research Board in the TCRP Report 48 gives a list of the very basic tasks all integrated models should accomplish. The list states, "integrated urban models should be

- Theoretically Sound
- Result-Driven
- Responsive to the issues faced currently by the MPOs, transit operators, and other urban transportation planners
- Cognizant of the regional, state, national, and global demographic and economic interrelationships
- Practical to operate
- Sufficiently flexible
- Presentable" (Miller, 1999)

These factors are the basis for achieving an adequate model for application.

The TCRP Report 48 shows what transportation – land use modeling techniques are capable of and what the strengths and weaknesses of various models are in relation to particular goals/tasks. (Southworth, 1999)

In 1995 at an international conference held in Dallas by the Travel Modal Improvement Program (TMIP) to report on land use modeling, a review of currently – existing models was developed. The following figure (Figure 5.6) presents the review to show an overview of their findings. (Waddell, 2002)

- There has been insufficient data validation and testing of models in the U.S.
- Most existing models are not sufficiently sensitive to policy issues, nor are they geared to understanding by non-modelers.
- Existing models do not adequately incorporate the land development decision-making process, nor are they sufficiently linked to consumer choices.
- Current land use models are not adequately linked to transportation models or environmental models and do not allow a valid assessment of the interaction among land use, transportation, and environmental impacts.
- There are many incompatibilities of zonal systems being used.
- Data, especially employment data, is a tremendous problem for existing models.
- There is an absence of a clear, describable basis of theory for current land use models.
- Generally, land use models are far too dependent on transportation modeling output and assumptions, and there is insufficient interaction between the two.
- Public transit is not adequately represented in land use or transportation.
- In general, there is too little behavioral content to the existing land use models.
- Existing models require excessive resources, effort, and execution time.
- Existing models are not capable of accounting for urban development as an incremental process, but are static cross-sectionally.
- Current models appear suitable for predicting urban sprawl, but are unable to assess controlled growth.

Figure 5.6 Review of Existing Models for TMIP 1995

Source: Waddell; 2002; *Analytical Tools for Land Use, Transportation, and Growth Management*

This listing shows that the currently–existing models are not completely adequate to say the least. This critique suggests what qualities are needed for an adequate integrated model. An understanding of what constitutes a good model comes from the same TCRP Report 48. This report goes into detail describing the ideal integration model concept, which can be seen in the following figure (Figure 5.7). The same report also gives a summary, in table form (Figure 5.8), of the attributes that the ideal integrated model should have. Both the figure and the table are good overviews of the so-called "ideal" model. (Miller, 1999)

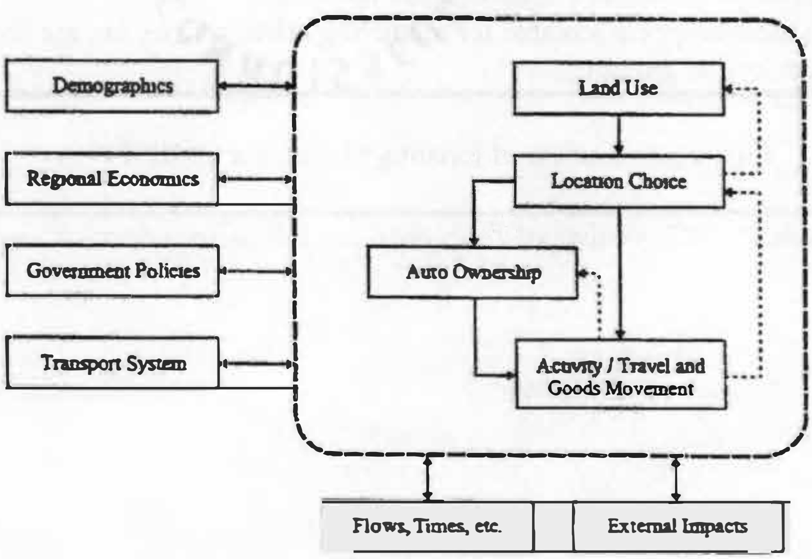

Figure 5.7 Idealized Integrated Urban Modeling System

Source: Miller; 1999; *Integrated Urban Models for Simulation of Transit and Land Use Policies.*

PHYSICAL SYSTEM

Time: Dynamic evolution of the system state in 1-year time steps. System state generally not in equilibrium. Interactions between long-term and short-term processes are "properly" accounted for.

Land: The basic unit of land is the individual lot.

Building Stock: Building stock is explicitly represented. Each lot has a certain amount of floor space, characterized by type, price, and so forth.

Transportation Networks: Full, multimodal representation of the transportation system used to move both people and goods. Sufficient spatial and temporal detail to properly model flows, network performance, emissions, and so forth. Ideally, a 24-hr network model to be used.

Services: Sufficient representation of other services for the purpose of modeling land development decisions.

DECISION MAKERS

Persons and Households: Both persons and households are explicitly maintained (with appropriate "mappings" between the two entities) in sufficient detail to model the various processes of interest.

Firms: Explicitly represented. Firms are at least as important as households in the overall system: they occupy land/floor space; they employ workers; and they buy/sell goods and services from/to themselves and households. Firms are modeled in sufficient detail to capture adequately their behavior within these various roles.

Public Authorities: Represented within the model to the extent they generate purely endogenous effects (e.g., employers of workers, demander/supplier of services, and so forth). Will remain represented largely by exogenous inputs to the model.

PROCESSES

Markets: Land development, residential housing, commercial floor space, and labor all function within economic markets, which possess demand and supply components, and price signals, which mediate between demand and supply. These economic markets must be explicitly modeled if their behavior over time is to be captured properly.

Demographics: Demographic processes should be modeled endogenously so as to ensure that the distribution of population attributes (personal and household) are representative at each point of time being modeled and are sufficiently detailed to support the behavioral decision models being used.

Regional Economics: Essential components of urban production/consumption processes should be modeled endogenously. The model should also be sensitive to macro exogenous factors (e.g., interest rates, national migration policies, and so forth).

Activity/Travel: The travel demand component of the integrated model should be activity-based and sufficiently disaggregated so as to properly capture trip makers' responses to a full range of transportation policies, including ITS and TDM.

Automobile Holdings: Household automobile holdings (e.g., number of vehicles and by type) should be endogenously determined within the model.

Figure 5.8 Summary of Ideal Integrated Model Attributes

Source: Miller; 1999; *Integrated Urban Models for Simulation of Transit and Land Use Policies.*

The TCRP Report 48 points out three important conclusions of the present models available. One of the conclusions states, "all currently operational models fall short of the ideal model to varying extents." (Miller, 1999) Thus there truly is no one perfect model for showing the integration of land use and transportation. However, the report provides/suggests/gives insight about recommendation on how to achieve the "perfect model" or what future models should do.

For future models, many suggestions have been presented to planners and developers in an effort to create a perfect integrated model. Paul Waddell wrote an article titled, "Analytical Tools for Land Use, Transportation, and Growth Management which goes over most of the aspects already presented. Waddell includes a table (Figure 5.9), reprinted following, from the TMIP that lists suggestions for the development of new models. These suggestions are intended to be the basis for any new design of models to show the integration of land use and transportation planning.

Selection of an Integrated Model

The selection of a model is a very important step in the entire integrated planning process. The selection of a specific model can lead a planning agency to forecast for the future and come out with great accomplishment or it can lead to total disaster. Selecting the right model is a critical aspect of planning for the future.

Before diving into model selection an agency has to know what it is trying to achieve. By articulating needs, a planning agency can begin to gain a sense of its goals.

- Modeling efforts should move fairly quickly toward random utility-based models.
- New models must be behaviorally based, and the underlying theory should be clear. Major research is required into the behavior of the actors involved.
- New models should place greater emphasis on their use for policy analysis, planning, and sensitivity testing, within an integrated land-use, transportation, and environmental framework.
- Models should be more sophisticated about varying temporal and geographic scales relevant to different processes in urban development.
- Models must be capable of bi-directional aggregation/disaggregation.
- In developing new models, the cost-effectiveness of the modeling strategy as a whole should be studied.
- Microsimulation holds promise, and should be considered in any new modeling system, although it is very data hungry. It should also not be the only method considered. Research into synthetic household data at the micro-level and use of other existing databases will be required.
- Model development should draw on disciplines beyond transportation, including economics, geography, logistics, computer science, and planning.
- New models should be modular in nature, not monolithic.
- GIS must be used with any new models developed. Remote sensing should be investigated as a means of monitoring land-use.

Figure 5.9 Suggestions for New Models for TMIP 1995

Source: Waddell; 2002; Analytical *Tools for Land Use, Transportation, and Growth Management*

A summary table is presented in Samuel Seskin's article, "Guidance for Land Use Impacts of Transportation," that shows transportation investments and policies that can be implemented by planners and their corresponding impacts and mitigating factors. The following table (Table 5.1) shows land use impacts of highway investment and policies. The second table (Table 5.2) shows a summary of land use impacts on transit investments and policies. The final table (Table 5.3) shows a summary of impacts of land use policies on travel demand. (Seskin, 1999)

These tables outline what planners may be trying to achieve in the future of the integration of land use and transportation, which in turn leads to comprehension of what the basis for the selection process should be. Oryani states in simplistic terms that the list of models can be narrowed by making sure that they are "commercially available, operational, are used in multiple locations, and are theoretically sound. (Oryani, 1999) This is a very general basis, but a good one, for the selection process. Planning agencies should follow these four guidelines to ensure narrowing of options in the selection process.

The Travel Modal Improvement Program released an article by Britton Harris that gives planners some recommendations on the selection process. These recommendations are:

- A model should be selected which is moderately disaggregated and whose underlying concepts are as realistic and as economically-based as possible
- Transportation conditions and available choices as to housing, industrial sites, access to amenities, and to the labor force, should enter intimately into all locational decisions which are modeled in the system

Table 5.1
Summary of Land Use Impacts of Highway Investments and Policies

Action	Land Use Elasticity	Land Use Impact	Mitigating Factors
New Facilities	High	Redistribution of metropolitan growth to highway corridors. Decentralization of population and employment. Increased land values and concentration of development around interchanges.	Local and regional economic conditions. Degree of impact on regional accessibility. Congestion levels Local land use policies NIMBYism
Added lanes, intersections	High	Same as above, but to a lesser degree.	Same as above.
Automated highway systems (AHS)	High	Decentralization of population and employment. Increased land values and concentration of development at nodes and terminals. Possibly new towns.	Magnitude of change in travel speeds. Extensiveness of system. Cost of use. Local land use policies. NIMBYism
System management	Low	None likely.	Levels of congestion and latent demand.
Congestion pricing	High	Unknown. Possible shift of population and jobs toward more accessible locations. Possible shift of population and employment to exurban areas.	Local and regional economic conditions. Spatial extent of pricing policy. Degree of congestion. Availability of alternative modes, routes.
Parking pricing, management	High	Unknown. Possibly increased development of major employment centers. Likely increased development density.	Local and regional economic conditions. Spatial extent of pricing policy. Availability of alternative modes. Long-run incidence of parking fees.
Vehicle, fuel tax	Moderate	More compact development if cost of driving high enough to encourage use of other modes.	Magnitude of tax. Availability of alternative modes.
Transportation demand management	Low	None likely.	N/A
Safety improvements	Low	None likely.	The extent to which the improvement changes capacity or accessibility.

Source: Seskin; 1999; *Guidance for Land Use Impacts of Transportation*

Table 5.2
Summary of Land Use Impacts of Transit Investments and Policies

Action	Land Use Elasticity	Land Use Impact	Mitigating Factors
New rail facilities	Moderate	Increased land values and development density. Redistribution of development to downtown, station areas. Decentralization of population.	Local land use policies. Degree of impact on accessibility. Local economic conditions. Stations access and local circulation pattern. Corridor congestion levels.
Rail extensions, stations	Moderate	Same as above, to a lesser degree.	Same as above.
New high capacity arterial bus lines, stations	Moderate	Possible redistribution of development to major bus transit corridors.	Local economic conditions.
Change in local service	Low	Possible redistribution of development to major bus transit corridors.	N/A
Fare policy changes	Low	None expected.	N/A
Safety improvements	Low	None expected.	Whether the improvement changes perceptions about passenger safety.

Source: Seskin; 1999; *Guidance for Land Use Impacts for Transportation*

Table 5.3
Summary of Land Use Policies on Travel Demand

Action	Travel Demand Elasticity	Travel Demand Impact	Mitigating Factors
Compact development	High	Reduced motorized travel. Increased transit use. Increased non-motorized travel. Shorter Trips.	Relative distribution of population and employment. Level of density. Metro development patterns. Transit availability and level of service.
Dispersed development	High	Increased vehicle miles of travel. Decreased use of transit and non-automotive modes. Higher speed travel. Trip chaining.	Metro development patterns. Transit availability and level of service. Parking pricing and management. Taxes on auto use.
Transit oriented development (TOD)	Moderate	Reduced motorized travel. Increased transit use. Increased non-motorized travel. Shorter Trips.	Relative location of TOD within metro area. Density and other characteristics of the TOD.
Jobs-housing balance	Low to moderate	Reduced vehicle miles of travel.	Zoning restrictions. Importance of non-employment factors on location. Degree of match between income levels of workers and housing costs.

Source: Seskin; 1999; Guidance *for Land Use Impacts of Transportation*

- An accurate delineation of choices implies that the model will distinguish among different types of housing and other developed space, or different types of land for development
- The model should be doubly constrained, and with meaningful constraints at both origins and destinations; whenever possible, the equilibrium which is sought should be a form of "market clearing"
- The degree of disaggregation should cover two to four types of households, probably separated by income level, many types of housing, and at least three types of employment, including manufacturing, retail trade, and other services, some of which should be broken into subclasses
- Data requirements and methods of calibration should be well-specified by the vendor, with the cooperation of the users
- Running times and equipment requirements are very important, and special consideration must be given to trade-offs between speed and accuracy. (Harris, 1996)

While the above factors are critical in the selection of an appropriate model, one of the most important driving factors of the whole selection process is the issue of cost and resources. Cost can determine very rapidly whether or not a planning agency can select a specific model. A large city like the top 35 MPO's might spend considerably more on a model selection than a city like Knoxville, TN; in practical terms cost is a basic underlying issue for all planning agencies in the selection process.

Data requirements can also be an important deciding factor. For every model available, data (statistical) has to be acquired to make the model work properly. The type of data needed is a factor to be considered before selecting a model. If a planner does not have the type of data required for a model or is not willing to collect it, that model cannot be considered as a serious option. This issue of data requirements also brings us back to the issue of cost: what is the planner willing to spend on the collection of data?

Thus, in the selection process, certain questions arise: Can we afford it? Do we have the data? Will it work for our region? This last question is critical to avoid a decision that may have drastic consequences. Planners must consider whether or not a model can be used for only a specific region or whether it can be used interchangeably from region to region.

These are some of the basic issues that arise in the selection of an integrated land use and transportation model for use in a particular region. Some issues are not part of the main decision-making process. One such issue is "Does the model do what we expect?" Some other important issues are:

- Can we calibrate and run it (calibration needs, time/staff capabilities)?
- How efficient is it?
- Does it need a traffic model?
- Can we explain it (logical)?
- Are we sure it works (success stories)?
- Who will have the ownership?

These are some of the main issues that are planners need to take into account in deciding upon an integrated travel model. After planners evaluate these criteria they then need to decide upon how to actually find the best model that suits their needs. The best method is by producing a decision matrix.

A decision matrix is a table that allows one to evaluate certain aspects based on criteria. These criteria are the same issues that are dealt with in the decision making process described above. The matrix is set up in table form to allow for scores to be given to the different models to quantify which model is the best possible one for an agency.

The first step is to follow the basic steps of selection described above in order to identify a core list of potentially appropriate models. After the model list (which can be altered later) is chosen, criteria for evaluation are then decided upon. An agency can select criteria by determining which are the most significant to their selection. They can then weigh the criteria by establishing which issues are the most and least important to them. This weighing can be done by calculating weights into the scores or by placing criteria in order of importance.

Once the model list is completed and the criteria have been decided upon and given respective weights a score can be given for each criterion that needs to be met. Scores determine the outcome of the decision process and are determined by a scientifically – best-guess estimate. The scores need to be as accurate as possible; they should show no bias towards any one model.

Scoring the criteria is by far one of the most important part of the matrix process: accurate scoring can help planners make the right decision and inaccurate scoring can result in sheer disaster. Once the scores are all assigned for all criteria for each model, the scores are added up for each model. The outcome of these calculations is the determining factor for which model to choose in the matrix process. At this point, the part in which the planning firm makes the ultimate final decision as to whether or not to select the integrated model that has been chosen as the best model by the decision matrix.

Below are two basic examples of the decision matrix. The first (Table 5.4) shows that the model list is on the top with the criteria listed down the side and the calculation totals on the bottom. The second matrix (Table 5.5) shows the models on the side with the criteria placed on the top and the totals placed on the opposite side of the models. This second matrix is not the best model for use due to the fact that it is a bit harder for the average person to grasp an understanding of its content quickly.

Table 5.4
Example of Decision Matrix

	Model 1	Model 2	Model 3
Criteria 1	Score	Score	Score
Criteria 2	Score	Score	Score
Criteria 3	Score	Score	Score
Totals	Total	Total	Total

Table 5.5
Example 2 of Decision Matrix

	Criteria 1	Criteria 2	Criteria3	Totals
Model 1	Score	Score	Score	Total
Model 2	Score	Score	Score	Total
Model 3	Score	Score	Score	Total

A decision matrix can be an excellent way of deciding upon an integrated land use transportation model. Knowing how to work a decision matrix is only half of the battle. Planners must decide on the criteria and which models to evaluate before filling in the matrix. This has shown a method of reaching a possible ideal integrated model. The following chapter will show a case study for the Nashville Metropolitan Planning Organization of how the decision matrix can be applied to a specific region.

Summary

The land use and transportation relationship and the need to consider land use and transportation in an integrated plan have already been established. The question has arisen as to how to decide upon the ever-growing list of integrated models that are available. This chapter has described an appropriate method for the selection process.

Land use / transportation linkages were described to show the importance of the integration, and to explain why the integrated models for planning are needed. The relationship showed that there exists and cycle that is never ending due to the fact that things are always changing in the planning realm.

After the linkages were described, a summary of what makes the "ideal" integrated model was provided. This section provided basic information about what it takes to make a good model. It also gave some recommendations for the development of new models to make them more ideal. It can be seen from this discussion that there may never be a perfect model for integrated land use and transportation planning, but one has to wait and see where technology will take us in the future.

The final part of this chapter dealt with the process of actually selecting the appropriate model to fulfill the requirements of a specific region. Selecting a model is a difficult process because it takes a basic knowledge of what is currently available and how the available models can be applied to your particular region. The decision matrix was introduced as a tool to help planners simplify the selection process. The agency or firm making the selection decides upon the criteria. Scores are given and calculated with the weights of the criteria to show quantitatively the most appropriate model. A decision matrix gives a visual representation of the goals that the planner is trying to accomplish by the selection of the model.

This chapter has provided the planner with the basic understanding and method for deciding upon a proper model that shows the integration of land use and transportation. Some models currently available can meet some of the needs of planning agencies, but no model fits every region's needs. Tokyo, Japan is not the same as Los Angeles, California and London, England is not the same as London, Kentucky; thus, these diverse cities should not be relying upon the same integrated planning models. The decision as to whether or not to use a planning model is a relatively simple one; the difficulty arises with the question, "Which model will work best?" This chapter has suggested how planners should address this question.

Chapter 6

Case Study

Introduction

The process for selecting an appropriate integrated land use and transportation model has been outlined/described in the previous chapters. How this selection process can be applied is illustrated in this chapter, which chronicles a case study for the Nashville MPO, in which the selection procedures described above were used to help the planning agency choose the best model for their own integrated planning needs.

Case Study for Nashville Tennessee MPO

The state of Tennessee was one of six states that were issued grants from the National Governors Association to study the integration of land use and transportation. Nashville Metropolitan Planning Organization (MPO) was the region where the state decided to conduct the study mandated by this grant. The MPO region has already begun to forecast that population growth is going to greatly affect the surrounding landscape and land uses.

There are several organizations within the Nashville region that deal with the planning process. Federal law requires all cities that have a population of 50,000 or more to maintain the "3-C" (Continuing, Comprehensive, and Cooperative) planning process by means of a Metropolitan Planning Organization (MPO). The Nashville MPO functions under a committee structure comprised of an Executive Board and Technical Coordinating Committee (TCC) and the planning staff. The Nashville MPO is comprised of five counties: Davidson, Rutherford, Sumner, Wilson, and Williamson.

In contrast, the Greater Nashville Regional Council (GNRC) consists of thirteen mostly urbanized counties and 52 cities around the Nashville region. The GNRC is the regional planning and economic development organization for this area. Full Council membership includes each mayor and county executive, four minority members, one industrial representative from each county, and two members of the General Assembly. The counties served by the GNRC include Cheatham, Davidson, Dickson, Houston, Humphreys, Montgomery, Robertson, Rutherford, Stewart, Sumner, Trousdale, Williamson and Wilson. It includes two Metropolitan Statistical Areas (MSA), Nashville and Clarksville.

Also, Cumberland Region Tomorrow is a private sector regional organization working with the public sector to support and encourage growth planning, with emphasis on land use, transportation, and preservation of rural landscape and the character of the region's communities. Cumberland Region Tomorrow is a non-profit, citizen-based organization dedicated to planning for the future livability and economic vitality of the ten county middle Tennessee region. The ten counties include Cheatham, Davidson, Dickson, Maury, Montgomery, Robertson, Rutherford, Sumner, Williamson, and Wilson. Figure 6.1 shows a county map of the selected ten counties. The Cumberland Region Tomorrow group has forecast population growth, which will create more households and more employment needs, which ultimately will, in turn, create a greater need for transportation. The population and employment forecast can be seen below. Figure 6.2 shows the population forecasts for the Nashville region, while Table 6.1 shows the employment forecast for the same region. These changes will eventually need to be met head on, and the accompanying transportation issues will also have to be addressed – yet

Figure 6.1 Cumberland Region Tomorrow Map of Ten Counties

Source: Cumberland Region Tomorrow; 2002;
http://www.cumberlandregiontomorrow.com

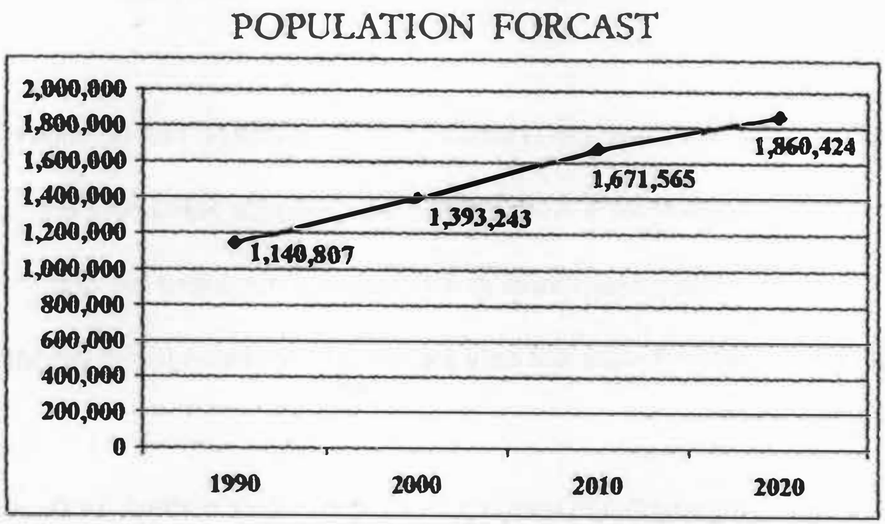

Figure 6.2 Forecast of Population in Nashville Region

Source: Cumberland Region Tomorrow; 2002;
http://www.cumberlandregiontomorrow.com

Table 6.1
2000-2020 Employment by County, TN

County	2000	2020	Increment
Cheatam	11,650	16,030	4,380
Davidson	531,020	631,540	100,520
Dickson	23,390	31,620	8,230
Maury	45,940	60,940	15,000
Montgomery	53,480	74,080	20,600
Robertson	24,140	32,660	8,520
Rutherford	105,330	177,810	72,480
Sumner	59,080	83,410	24,330
Williamson	78,720	129,460	50,740
Wilson	40,830	59,570	18,740

Source: Cumberland Region Tomorrow; 2002;
http://www.cumberlandregiontomorrow.com

another example of the land use transportation cycle. (Cumberland Region Tomorrow, 2003)

In working with the Center for Transportation Research (CTR) in Knoxville Tennessee, the National Governor's Association, and Nashville MPO, as a pilot project, the researcher was able to help assist them in defining analytical land use and transportation models that will work not only for the MPO but also for all the MPOs in Tennessee.

It was decided that a decision matrix was an appropriate method for the selection of the integrated model. The CTR had to work closely with the MPO to understand what the model needed to accomplish. Once the general needs for the model were determined, the researcher and CTR staff began researching the models that were currently available that met their requirements. The research team began to comprise a list of models that met the region's basic requirements. Seven models, all considered to be regional models, were chosen. Three of the models were integrated with travel demand models, while the other four models did not have a formal travel model component. Those integrated with travel demand include UrbanSim, ULAM, and CorPlan; and those that used surrogates for trips and could operate without a model included, LUCI, What If, Spreadsheet Manual Delphi, and INDEX Forecasting.

UrbanSim, according to the manufacturer's website, "is a software based simulation model for integrated planning and analysis of urban development, incorporation the interactions between land use, transportation, and public policy." (UrbanSim, 2002) The model is available for download through the Internet. The major players of the model are households, businesses, developers, and government. An outline of how UrbanSim works can be seen in the following figure (Figure 6.3). The advantages and disadvantages of UrbanSim can be seen in the NCHRP-466, produced by the Louis Berger Group for the National Research Council. Some of the major advantages include the lack of a licensing fee, the capability for modeling impacts of land use, and the placement of into GIS based maps. The most important disadvantage is the substantial amount of data that is required, down to the parcel level. (The Louis Berger Group, 2002)

ULAM (Urban Land Allocation Model) was designed for the state of Florida to provide an automated process to allocate future growth in the form of countywide population and employment totals down to the traffic analysis zone (TAZ). The figure following (Figure 6.4) shows a map of Florida counties that are currently using the ULAM model. The user counties include Bay, Broward, Charlotte, Citrus, Hernando, Hillsboro, Indian Beach, Leon, Martin, Palm Beach, Pinellas, and St. Lucie. According to the ULAM website, the model "is a land use package which consists of over sixty

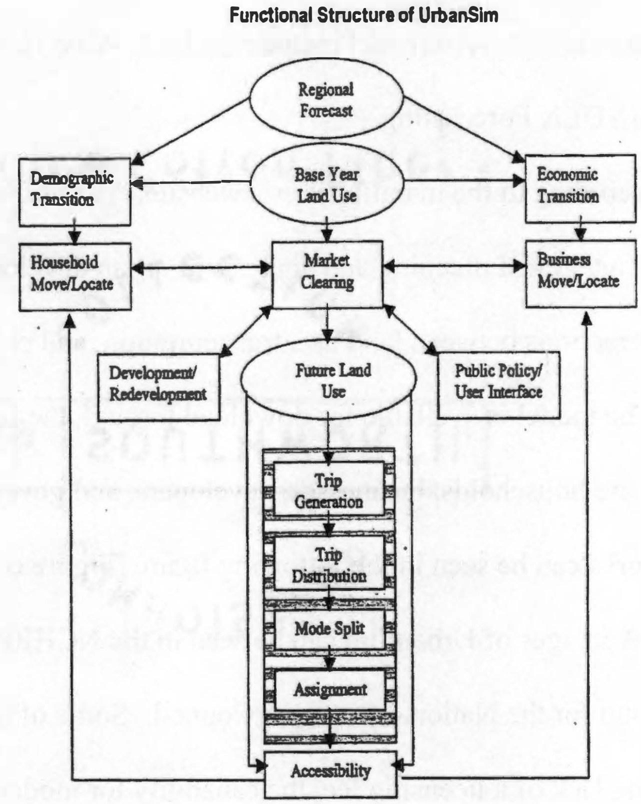

Figure 6.3 Functional Structure of UrbanSim

Source: UrbanSim; Retrieved September 2002; http://www.urbansim.org

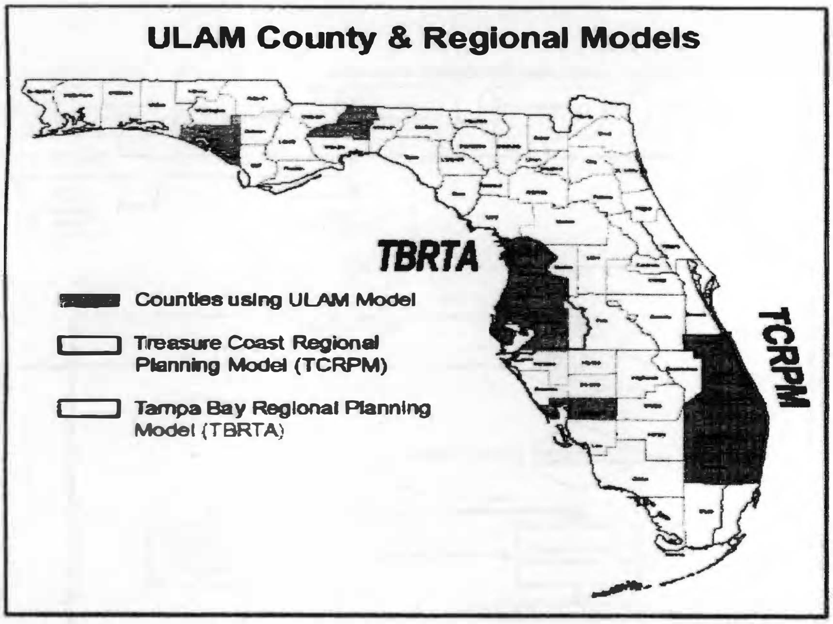

Figure 6.4 ULAM County Map

Source: Transportation Planning Services, Inc.; 2002; *ULAM 99*; http://www.ulam.org

separate programs used for a variety of planning applications in addition to the allocation of future growth to traffic zones." (Transportation Planning Services, 2003) This model also has a GIS interface to allow for visual simulation. The following diagram (Figure 6.5) shows how ULAM works. This model can be used in numerous planning applications and is an easily accessible and modifiable program.

The CorPlan model was developed for and applied to the five-county area surrounding Charlottesville, Virginia, which includes the Thomas Jefferson Planning District Commission and the Charlottesville – Albemarle MPO. The model, which is funded by the Federal Highway Administration (FHWA), is a "Geographic Information System (GIS) model that estimates regional land-development potential using prototypical community elements as its building blocks." (Sinclair, 2003)

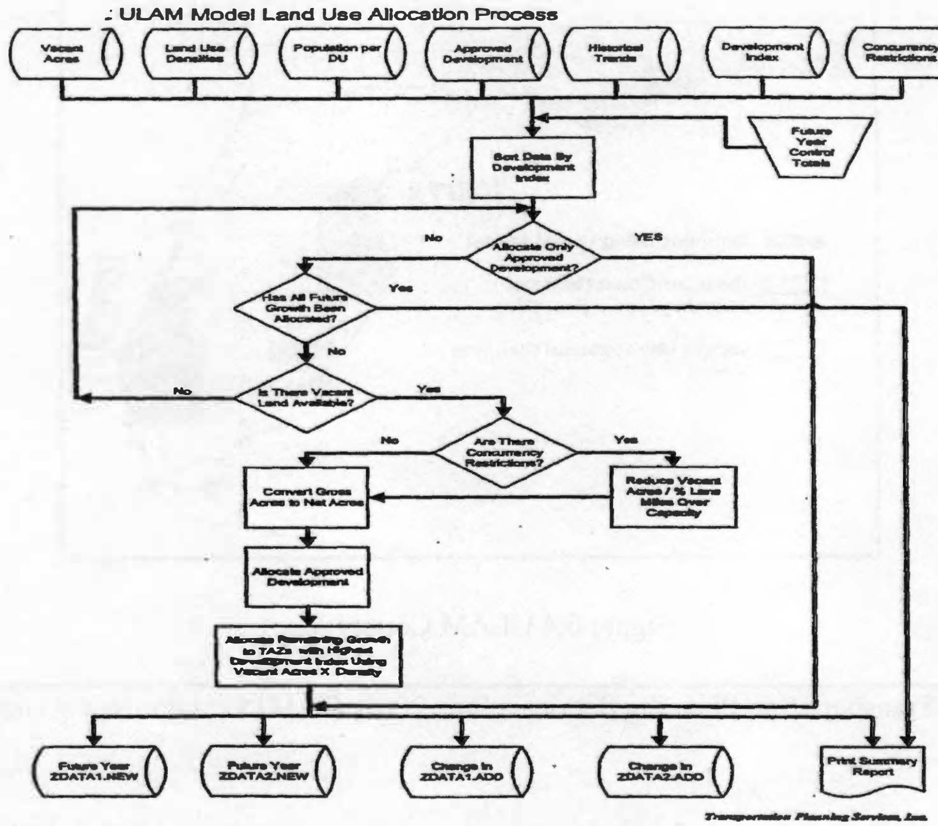

Figure 6.5 ULAM Land Use Allocation Process

Source: Transportation Planning Services, Inc.; 2002; *ULAM 99*; http://www.ulam.org

CorPlan focuses on alternative land use scenarios, their transportation implications, and visioning techniques. One of the main notable aspects of the model is the use of a neighborhood-level "community elements" concept that lends itself well to public input. The main strength of this model is that it works well with the public. One of the major limitations to the model is that it does not directly provide transportation, social, or economic information, but this information can be derived from model outputs.

The models not supporting travel demand include, LUCI, What If, Manual Delphi, and INDEX. They can model future developments according to data and or forecasts but do not incorporate a formal travel model. LUCI, What If, and Manual Delphi models were described in the Inventory Chapter (Chapter 6). INDEX "forecasting" is a modeling software support system that is based on GIS, which measures the conditions and performance of communities and their plans. According to the Criterion website (the developers of INDEX), INDEX is used "to simulate alternative land use transportation planning scenarios and evaluate their outcomes with environmental performance." (Criterion, Oct. 2003) This model has been well received by many planning and governmental agencies. The first table (Table 6.2) shows the clients who are currently using the INDEX model for some applications. The following figure (Figure 6.6) shows some locations where it is being used and their specific users. INDEX is highly advanced software that requires training and a basic knowledge of GIS. The influence of INDEX model is rapidly growing in the field, to meet the specific needs of MPOs and regions around the country. A version of INDEX, called "snapshot", is already being used in the Nashville MPO in efforts to help create plans, implement plans, and achieve plans, but the version used in Nashville does not address the transportation

Table 6.2
INDEX Applications

Location	Application	User
Chicago, Illinois	Growth forecasting	N.E. Illinois Planning Commission
Nashville, Tennessee	Development evaluation	Metropolitan Planning Dept.
Chula Vista, California	Energy-efficient land-use planning	City of Chula Vista
Sacramento, California	Comprehensive land-use/transportation planning	County of Sacramento
Madison, Wisconsin	Community planning and development impact analysis	County of Dane
Palm Beach, Florida	Rural preservation/land-use planning	County of Palm Beach
Atlanta, Georgia	Regional land-use and transportation planning	Georgia Regional Transportation Authority
Sacramento, California	Community plan implementation monitoring	City of Sacramento
Tampa, Florida	Inner city neighborhood revitalization	City of Tampa/ Florida DCA
Tallahassee, Florida	Comprehensive plan implementation monitoring	City of Tallahassee and Leon County
Atlanta, Georgia	Alternative urban design evaluations of infill	U.S. Environmental Protection Agency
Sacramento, California	Analysis of infill vs. suburban development	Natural Resources Defense Council
Orlando, Florida	Evaluation of development plans	City of Orlando
British Columbia, Canada	Land-use/electricity conversion for energy planning	BC Hydroelectric Authority
30 cities and counties statewide	Sustainable community indicators	Florida Department of Community Affairs
40 jurisdictions and agencies nationally	Smart growth urban planning	U.S. Environmental Protection Agency
Sacramento, California	Urban design for indirect source emissions reduction	Sacramento Metro Air Quality Mgmt. District
West Palm Beach, Florida	Infill vs. Greenfield development	U.S. Environmental Protection Agency
Montgomery County, Maryland	Infill vs. Greenfield development	U.S. Environmental Protection Agency
San Diego, California	Low-income neighborhood revitalization	San Diego Assn. of Governments
Beaverton, Oregon	Transit station area master planning	Oregon Department of Energy
Coquitlam, British Columbia	Sustainable community planning	City of Coquitlam
Ft. Lewis, Washington	Family housing area livability rating	U.S. Army

Source: INDEX website; 2003; http://www.crit.com

Local Governments
City of Sacramento, CA
County of Dane, WI
City of Tallahassee, FL
City of Chicago, IL
County of Sacramento, CA
City of Aurora, CO
City of Orlando, FL
City and County of San Francisco, CA
City of San Jose, CA
City and County of Denver, CO
City of Boise, ID
City of Vancouver, B.C.
County of Palm Beach, FL
City of Portland, OR
City of Tucson, AZ
Union of British Columbia Municipalities

Regional Agencies
Metropolitan Nashville-Davidson County, TN
Northeastern Illinois Planning Commission
Burlington Vermont Metropolitan Planning Organization
Georgia Regional Transportation Authority
Sacramento Regional Transit District
South Florida Regional Planning Council
Capital Regional District of Victoria B.C.
Portland Oregon Metro
Metropolitan Municipality of Seattle, Washington
Lake Tahoe Regional Planning Agency
San Diego Association of Governments
Sacramento Metropolitan Air Quality Management District
South Florida Water Management District
Greater Vancouver B.C. Regional District

Corporate and Non-Profit
Natural Resources Defense Council
Florida A&M University
Environmental Systems Research Institute
Hewlett-Packard Co.
International Council for Local Environmental Initiatives
California Local Government Commission
Mitsubishi Corporation
Nike Inc.
Oregon Institute of Technology
San Diego State University
Swedish Council for Building Research
University of British Columbia
Electric Power Research Institute
University of Southern California

State and Federal Agencies
Florida Department of Community Affairs
U.S. Environmental Protection Agency
Oregon Department of Land Conservation & Development
U.S. Department of Housing & Urban Development
California Department of Transportation
U.S. Department of Energy
Nevada Department of Commerce
California Energy Commission
U.S. Department of Transportation
Oregon Department of Energy
Arizona State Energy Office
U.S. Army
U.S. Navy

Utilities
Southern California Edison Co.
Pacific Gas & Electric Co.
Los Angeles Water and Power Dept.
Sacramento Municipal Utility District
British Columbia Hydroelectric Authority
Pacific Power & Light Co.
Seattle City Light Dept.
Northern California Power Agency

Figure 6.6 INDEX Clients

Source: INDEX website; 2003; http://www.crit.com issues that the region is currently facing. (Criterion Nashville MPO, July 2002) See Appendix D for more details on INDEX.

The research staff began a dialogue with the MPO in an effort to gain a more specific understanding of what they wanted to achieve. With this dialogue came a thorough understanding of what the agency was hoping to achieve with the selected model. The staff began to comprise a list of criteria. These criteria had four basic main categories that included functionality ("Does it do what we expect?"), efficiency, robustness, and ownership. The entire list includes many criteria, but generally all of them fall under these four main categories. Below is a listing of all the criteria.

- Sensitivity to Transportation Policies
- Sensitivity to Land Use Policies
- Output-Friendly Software
    - Visualization
    - Replication
    - Clarity (Can we explain it?)
- Data Inputs
- Time/Staff Capabilities
- Cost
- Calibration Needs
- Functionality (Are We Sure It Works?)
- Transportation / Land Use Logic
- Land Use Behavioral Elements

- Transportation Logic
- Broad Application to TN
    - MPOs
    - Non-MPOs

The sensitivity to transportation policies deals with how well the model follows the transportation policies that are in place from the federal government and in the Nashville area; the sensitivity to land use policies also deals with the same issues but concerning the land use. The output-friendly software criterion refers to how well the model can be shown to others and how it can be replicated. Data input criterion focuses on the amount of information needed to run the model successfully. The time/staff capabilities makes reference to how much time it will take to run the model and how many people will be required to run it. The functionality deals with the issue of is it operational at the present time and does it work accordingly. The transportation / land use logic shows the need for the integration, how well it is integrated, and is it logical in its integration. The land use behavioral element and the transportation logic deal with the separate elements of the integration and how well they are used and applied to the model. The final criterion, broad application to TN, gives referral to how well the model can be applied in TN, broadly speaking.

Appendix A shows the first matrix prepared for the Nashville MPO before the weights were given. (The notes for the matrix are: 1. Satellite Data – These models include satellite information data. 2. GIS Data – These models include GIS data with the model. 3. Visualization Process - These include a visualization technique that allows a viewer to represent the forecast. 4. Needs Recalibration to Local Area – These need to be recalibrated to fit the local needs.) The staff felt that these criteria described the needs of the Nashville MPO and presented them to the NGA for decision and reflection. After the list was comprised the MPO gave further consideration and assigned what the criteria's weights would be. Nashville sent the criteria back with their respective weights to be applied to the decision matrix. The weights were laid out as tiers to show that the first tier was the most important, and then the second tier, and so forth. The weights were given from the Nashville MPO as to which were of the most concern to them. Appendix B shows the numerical version of the Appendix A matrix.

We then placed the scored criteria into a matrix with the selected models. Each model was then evaluated for each of the criteria and was given an estimated – best judgment score. The matrix was completed with as much scientific soundness as possible. The totals for each of the models were then calculated for an average score. The same process then was completed for just the two top tiers to show the weighted score average. A copy of the completed matrix can be seen in Appendix C, showing the criteria weighted in form of placing criteria into tiers of importance and the respective score for each of the models and the outcomes.

The calculations showed that the top three models were INDEX, ULAM, and CorPlan. The staff then decided that since the CorPlan was still in the designing stages and relied on citizens it was necessary to not include this one. Thus, the staff decided to push forth the ULAM and INDEX Forecasting models due to their high scores and overall potential to the Tennessee MPO's and more specifically the Nashville MPO. ULAM is integrated with travel demand models currently in Florida; while INDEX is appropriate for areas beyond MPO's where a formal travel demand model is not available. INDEX suits travel patterns and accessibilities with quick response planning to change. The final model that is being placed before the Nashville MPO is ULAM out of Florida for the main reason of that it incorporates a regional travel model, while INDEX does not, and since Nashville already has a travel model this could be used sufficiently. Also there is not a lot of documentation on the successes of INDEX for application to different regions available. This is the main reasons why the research staff decided to promote the ULAM model.

Summary

National Governor's Association wanted to have research conducted to show what types of integrated land use and transportation models have been completed for the Nashville region. The research identified and described models that would potentially meet their needs. Also, the research described in detail how to go about the decision-making process for selecting the best model for their purposes. In conclusion, the research showed an appropriate model for selection for the Nashville MPO as a case study.

This chapter has gone through the entire case study for the Nashville MPO and has provided an example of how the method of selection for an integrated model has to be taken very seriously. ULAM is the model that is being proposed to the MPO in efforts that they will see the benefits of it. Ultimately, the decision rests in the hands of the MPO as to whether or not they will implement the model their regional planning field.

Chapter 7

Conclusion

The planning field has gone through many changes that have helped make certain areas a better place to live. Information technology has given so much additional help to this field that it is sometimes hard to keep up with all the latest high-tech advancements. Since planning processes were first implemented, planners have always focused on the future to allow for development.

Recognizing that present actions could have dramatic future impacts, planners began early on to develop forecasts that would allow them to get more accurate measures of the future of consequences resulting from different decisions. When dramatic growth of automobiles in society as a whole was placed before planners, they began realizing that land use issues and transportation issues had a relationship. This relationship began to be built into modeling techniques. With technology advancements and the invention of Geographical Information Systems (GIS), planners were better able to simulate and see the results that the models could produce.

This thesis has given examples of the research that has been done to show the need for the integration of land use and transportation. It has provided a history of land use, transportation, and integrated models. It has also made available an inventory and overview of some of the most common models available.

The report answers the main question as to how to select a model for a specific region. It reviews what the ideal model might include and suggests some recommendations for future development of integrated models. It shows that the decision matrix is the best method for the selection process, and explains how to develop and use the matrix for any regional planning area. The report concludes with a case study showing how the decision-making process was applied to aid the Nashville Metropolitan Planning Organization.

The integration of land use and transportation planning and modeling is a highly complex system that is continuing to challenge planning organizations throughout the world and especially here in the United States. The complexity is going to continue increasing with the ever-accelerating advances in technology. The selection of a specific model can contribute to great progress in a region or hinder the process. Thus, the selection process has to be very systematic and organized so that planners can make the most accurate and beneficial decisions for their regions.

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Appendixes

Appendix A

First Matrix Without Weighted Criteria or Scores

	D. Regional - No Travel Model				C. Regional - Travel Model		
1. Does It Do What We Expect?	LUCY(2)	"What If"(B)	Spreadsheet Manual Delphi	INDEX Forecasting(1)	URBANSIMS(2)	ULAM(3)	CorPlan(4)
Sensitive to Transp. Policies	0/–	0/–	–	+/0	+	+	0
Sensitive to LU Policies	+/0	+/0	–	+/0	+	+	+
Output Friendly							
Visualization	+	+	–	+	+	+	+
Replication	0	0	–	+/0	+	+	–
Can We Explain it?	0	0	–	+	+/0	0	0[3]
2. Efficiency							
Data Inputs	+/0	0	0	0	–	–	0
Time/Staff Capabilities	0	+/0	+	0	–	0/–	0
Cost	–	0	+	0	–	0/–	0
Calibration Needs	–	+/0	+	+/0	–	0/–	+/0
Are We Sure it Works?	–	–	–	+	0	+	+[3]
3. Robustness							
Transp/LU Logic	0/–	–	–	0	+	+	+/0
LU Behavioral Ement	0/–	0	–	0/–	+	0	0[3]
Transp Logic	0/–	–	–	0	+	+	+
4. Ownership							
Broad Application to TN	0/–[1]	+/0[2]	+	0/–	–	–	–
MPOs	0/–	+/0	+	+/0	0	0	+/0[3]
Non-MPO's	0/–	+/0	+	–	–	–	–

[1]Satellite Data
[2]GIS Data
[3]Visalization Process
[4]Needs Recalibration to Local Area

Appendix B

Matrix with Scores without Weights

(5 is best, 1 is worst)

CRITERIA	REGIONAL – NO TRAVEL MODEL				REGIONAL – TRAVEL MODEL		
	LUCY	"What If"	Spreadsheet Manual Delphi	INDEX Forecasting	URBANSIMS	ULAM	CorPlan
Sensitive to Transp. Policies	2	2	1	4	5	5	3
Sensitive to LU Policies	4	4	1	4	5	5	5
Visualization	5	5	1	5	5	5	5
Replication	3	3	1	4	5	5	1
Can We Explain It?	3	3	1	5	4	3	3
Data Inputs	4	3	3	3	1	1	3
Time/Staff Capabilities	3	4	5	3	1	2	3
Cost	1	3	5	3	1	2	3
Calibration Needs	1	4	5	4	1	2	4
Are We Sure it Works?	1	1	1	5	3	5	5
Transp./LU Logic	2	1	1	3	5	5	4
LU Behavioral Element	2	3	1	2	5	3	3
Transp. Logic	2	1	1	3	5	5	5
Broad Application to TN	2	4	5	2	1	1	1
Can be used in other MPOs	2	4	5	4	3	3	4
Can be Used in Non-MPOs	2	4	5	1	1	1	1

Appendix C

Completed Matrix

(5 is best, 1 is worst)

	CRITERIA	REGIONAL – NO TRAVEL MODEL				REGIONAL – TRAVEL MODEL		
		LUCY	"What If"	Spreadsheet Manual Delphi	INDEX Forecasting	URBANSIMS	ULAM	CorPlan
1st tier	Transp./LU Logic	2	1	1	3	5	5	4
	Can We Explain It?	3	3	1	5	4	3	3
	Are We Sure it Works?	1	1	1	5	3	5	5
2nd tier	Visualization	5	5	1	5	5	5	5
	Transp. Logic	2	1	1	3	5	5	5
	Data Inputs	4	3	3	3	1	1	3
3rd tier	Sensitive to Transp. Policies	2	2	1	4	5	5	3
	Sensitive to LU Policies	4	4	1	4	5	5	5
	Replication	3	3	1	4	5	5	1
	Time/Staff Capabilities	3	4	5	3	1	2	3
	Cost	1	3	5	3	1	2	3
	Calibration Needs	1	4	5	4	1	2	4
	Can be used in other MPOs	2	4	5	4	3	3	4
4th tier	LU Behavioral Element	2	3	1	2	5	3	3
	Broad Application to TN	2	4	5	2	1	1	1
	Can be Used in Non-MPOs	2	4	5	1	1	1	1
	Average	2.4	3.1	2.6	3.4	3.2	3.3	3.3
	Avg. using first, second tier	2.8	2.3	1.3	4.0	3.8	4.0	4.2

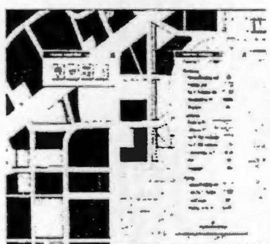
Appendix D

INDEX Information

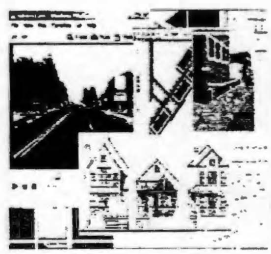
INDEX®

Planning Support Software

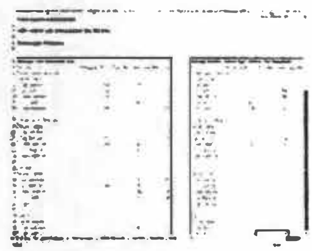
INDEX is a GIS-based planning support system that uses indicators to measure the performance of regional, community, and neighborhood plans. It is available in both standard and custom versions to help planners and citizens: 1) create plans through issues identification, alternatives analysis, and goal-setting; 2) implement plans by evaluating proposed development consistency with adopted goals; and 3) achieve plans by periodically measuring cumulative progress toward goals. The software's scope includes land-use, transportation, and environmental resources, and is capable of single point in time impact analyses or dynamic forecast analyses. INDEX is distinguished by its spatially-referenced multimodal travel network that provides genuinely integrated land-use/transportation evaluations.



Design
Create scenarios interactively with stakeholders.



Visualize
View outcomes with 3D modeling, video, and other media.



Analyze
Perform specialized technical analyses, e.g. air quality, stormwater, fiscal

After plan preparation INDEX converts to an implementation evaluation tool that examines the acceptability of proposed development projects. Proposals can be examined in two ways: the magnitude of change in existing conditions that would be created; and the degree of consistency with adopted plan goals. Detailed impact evaluations can also be prepared for travel, air quality, stormwater, fiscal, and developer financial returns.

Score
Evaluate scenarios and development impacts with stakeholder-selected and weighted indicators

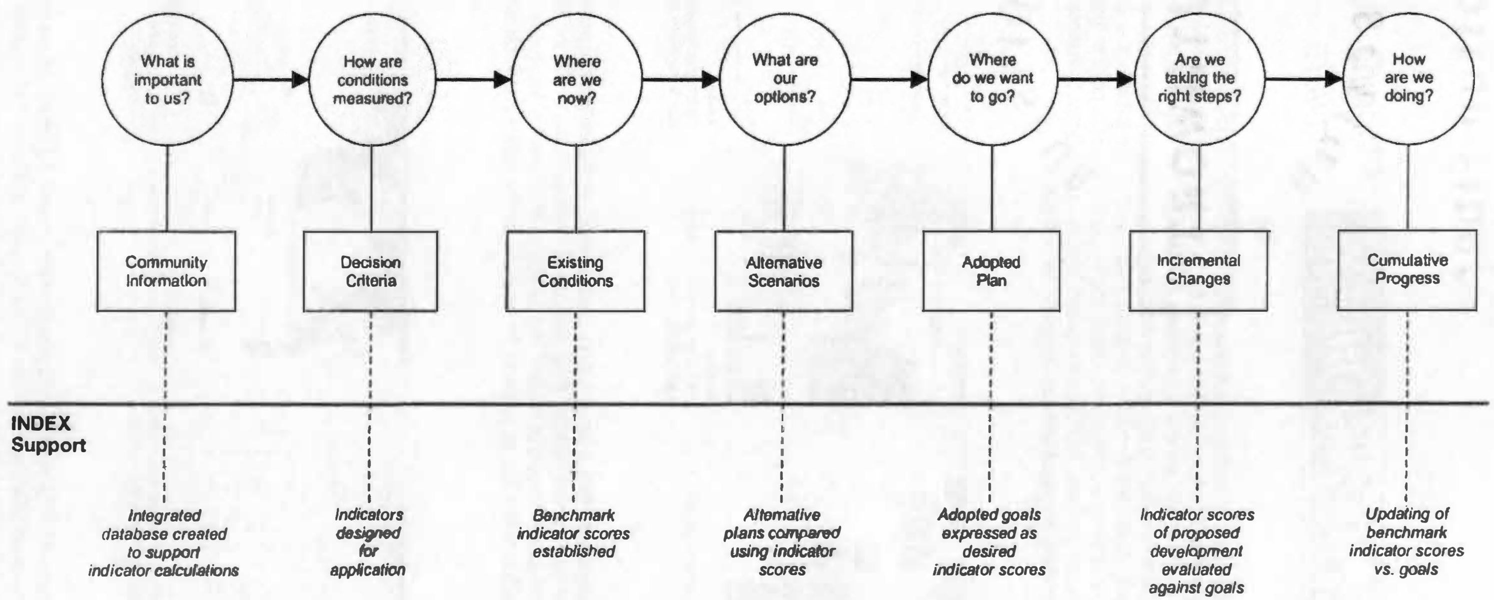
Compare
Identify trade-offs between alternatives and gauge acceptability.

Periodic Report Card
Gauge cumulative progress toward plan goals.

The last stage of INDEX application is periodic measurement of progress toward plan goals. Benchmark measurements can be updated annually or every few years, and cumulative progress toward goals reported. In this way, stakeholders can be assured of accountability over the life of a plan; and equally important, the need for mid-course adjustments can readily be seen and acted upon.

Integrating the Tool Into Community Planning

The Community Planning Process



INDEX® Frequently Asked Questions

What is INDEX?
INDEX is a GIS-based planning support system that uses indicators to measure the conditions and performance of communities and their plans. It is used to benchmark existing conditions, evaluate alternative courses of action, and monitor change over time. The software is marketed by Criterion Planners/Engineers of Portland, Oregon, and is available in standardized PlanBuilder and TransitNeighbor versions, custom versions developed for specific communities, or through modeling services provided by Criterion.

What is its history of use?
INDEX is one of the most widely distributed planning tools in the country, with over 80 organizations in 25 states equipped with the software since 1994. Approximately half of the users are city and county planning departments, a quarter are regional planning agencies, and the balance is divided among federal agencies, advocacy groups, and academic institutions.

What indicators does it use?
Criterion has a library of more than 100 indicators available for community-specific customization. Their topical scope ranges across land-use, transportation, housing, employment, infrastructure, and the natural environment. New indicators are often designed in collaboration with local stakeholders during customizations. PlanBuilder and TransitNeighbor come with standard sets of 58 indicators.

What are its geographic and temporal scopes?
INDEX can be applied to single neighborhoods, entire communities, and multi-jurisdiction regions. Its measurements can be calculated at either the parcel level or a larger user-defined area level, such as census blocks or traffic analysis zones. It can execute static analyses of a single point in time or dynamic analyses of spatial growth forecasts of up to 20 years.

What are its hardware requirements?
Minimum hardware requirements generally include a 450 MHz PC with 128 MB of RAM, a 17-inch monitor capable of 800 x 600 resolution with 32-bit color, and at least 25 MB of hard disk space for installation; up to 1.5 GB may be needed for applications.

What are its software requirements?
INDEX is built as an ArcView or a MapObjects-based application using any Windows operating system. ArcView 3.2a versions of INDEX also require ArcView Network Analyst 1.0b, and in some cases 3D Analyst and/or Spatial Analyst depending on customization specifications. Criterion is an ESRI Business Partner and Reseller.

What are its data requirements?
Data needs are determined by the scope and number of indicators in a given version. Typically this includes parcel-level GIS coverages of land-use, housing, employment, transportation, infrastructure, natural environment, and related community data. Data availability is a key consideration in designing each custom version of INDEX to insure that it's compatible with local conditions.

What are its standard outputs?
INDEX produces indicator results in numeric and spatial form; comparative charting of multiple case results; and documentation of all input parameters and assumptions. Optionally, scenarios can be visualized using 3-D modeling, photography, video, and drawings.

Can INDEX be linked to other models?
Yes, it can import and export data files to create linkages to other community planning models, e.g. travel demand models.

What user skills are required?
INDEX is usable by anyone familiar with ESRI products and GIS modeling generally. User organizations will need a model steward with advanced GIS experience for certain maintenance tasks.

Are training and technical support available?
Yes, both are included with PlanBuilder and TransitNeighbor purchases, and are standard components of custom projects.

How does someone obtain INDEX?
There are three ways to acquire INDEX: 1) purchase a standardized PlanBuilder or TransitNeighbor version; 2) purchase a custom version; or 3) retain Criterion to provide modeling services in cases where analysis, but not the software, is desired.

How much does it cost?
PlanBuilder or TransitNeighbor can be purchased for $3,900, including training and technical support. Custom version costs will depend on the type and scope of desired functionality, data availability, extent of public participation in the process, and amount of work shared between Criterion and local stakeholders. Criterion's fee is based only on its labor and expenses; there is no charge for the INDEX license. Organizations that sponsor custom versions may distribute copies to their stakeholders at no cost.

Where can additional information be obtained?
www.crit.com or e-mail info@crit.com.

Tool Comparison Matrix				
Status and Capabilities	INDEX®			
Year Introduced	1994			
No. of Users Nationally	82 in 25 states			
Topical Scope	Land-use, transportation, housing, employment, environment, others.			
Integrated Multi-Modal Travel Environment	Yes (walk, bike, transit, auto)			
Temporal Scope	Static and dynamic (up to 20 yrs)			
Geographic Scope and Resolution	Neighborhood, community, or region, at parcel level or higher.			
No. of Indicators	Library of over 100.			
Indicator Rating and Weighting	Yes, by stakeholder selection.			
Visualization	Photography, video, drawings; optional 3D modeling.			
Linkage to Other Tools	Yes: water use, stormwater runoff, fiscal impact, others; also Internet/web links.			
Documentation and On-Line Help	Technical user guide and community process guide.			
Training & Technical Support	Included with purchase.			
System Requirements	300 MHz PC, 128 MB RAM, 25 MB hard disc space, ArcView 3.2a, Network Analyst 1.0 b.			
Sales	$3900 PlanBuilder (two-seat license, training, support); custom versions by special quote.			
Modeling Services	Available at standard hourly rates.			

Appendix E

Some Integrated Models

Table 2. Some integrated and empirically applied land use—transportation models

Model	Useful References	Example Urban Studies
AMERSFOORT	Floor and de Jong(1981)[a]	Amersfoort, Utrecht, Netherlands; ~~Leeds, UK~~
BOYCE, ET AL	Boyce, Tatineni & Zhang (1992), Boyce, Lupa, Tatineni & He (1993)	Chicago
CALUTAS	Nakamura et al (1983)[a]	Tokyo, Nagoya, Okayama, Japan
CATLAS/NYSIM /METROSIM	Anas (1983b), Anas & Duann (1986). Anas (1992, 1994)	Chicago, New York
DORTMUND	Wegener (1982a,b; 1986, 1995a)[a]	Dortmund, Germany
KIM	Kim (1989)	Chicago
ITLUP	Putman (1983, 1991)[a]	San Francisco, Los Angeles Houston, Dallas, Portland, Others
LILT	Mackett (1983, 1990a, 1991a,b)[a]	Leeds, England; Dortmund, Germany; Tokyo, Japan
MASTER	Mackett (1990b, 1990c)	Leeds, England
MEPLAN	Echenique et al (1985)[a], Hunt & Simmonds (1993), Hunt (1993, 1994)	Bilbao, Spain; Sao Paulo, Brazil Santiago, Chile; Naples, Italy; Others.
OSAKA	Amano et al (1985)[a]	Osaka, Japan
POLIS	Prastacos (1986a,b), Caindec & Prastacos (1995)	San Francisco Bay Area.
PSCOG	Watterson (1993)	Puget Sound, Washington.
TRANSLOC	Boyce & Lundqvist (1987);[a] Lundqvist (1989)	Stockholm, Sweden
TOPAZ	Brotchie et al (1980)[a] ; Dickey and Leiner (1983), Sharpe (1978, 1980, 1982)	Melbourne, Darwin, Australia; Prince William Co. Virginia; Others
HAMILTON	Anderson, et al (1994); Kanaroglou, et al (1995)	Hamilton, Canada
TRANUS	de la Barra (1989)	Caracas, La Victoria, Venezuela

[a] indicates participation in the International Study Group on Land Use–Transportation Interaction (ISGLUTI) study; see Webster, Blye, and Paulley (1988).

Appendix F

Comparison of Some Integrated Models

Table 1 Summary of Comparison of Thirteen Land Use Models

Table 1 Summary of Comparison of Thirteen Land Use Models

Model	Subsystems modeled	Model theory	Policies modeled
POLIS *composite*	employment population housing land use travel	random utility locational surplus	land use regulations transportation improvements
CUFM *composite*	population land use	location rule	land use regulations environmental policies public facilities transportation improvements
BOYCE *unified*	employment population networks travel	random utility general equilibrium	transportation improvements
KIM *unified*	employment population networks goods transport travel	random utility bid rent general equilibrium input-output	transportation improvements
METROSIM *unified*	all subsystems except goods transport	random utility bid rent general equilibrium	transportation improvements travel-cost changes
ITLUP *composite*	employment population land use networks travel	random utility network equilibrium	land use regulations transportation improvements
HUDS composite	employment population housing	bid rent	housing programs
TRANUS *composite*	all subsystems	random utility bid rent network equilibrium land use equilibrium	land use regulations transportation improvements transportation-cost changes
5-LUT *unified*	population networks housing	random utility bid rent general equilibrium	transportation improvements
LILT *composite*	all subsystems except goods transport	random utility network equilibrium land use equilibrium	land use regulations transportation improvements travel-cost changes
MEPLAN *composite*	all subsystems	random utility network equilibrium land use equilibrium	land use regulations transportation improvements transportation-cost changes
IRPUD *composite*	all subsystems except goods transport	random utility network equilibrium land use equilibrium	land use regulations housing programs transportation improvements travel-cost changes
RURBAN *unified*	employment population housing land use	random utility bid rent general equilibrium	land use regulations transportation improvements

Source: "Review of Current and Future Land Use Models", Michael Wegener Ph.d.

Vita

Matthew Stuart Lambert was born in Front Royal, VA on March 31, 1977. He was raised for the first part of his life in the Northern VA – DC area. He then moved to Biloxi, MS. He graduated from Biloxi High School in 1995. From there, he went to Pellissippi State Technical Community College in Knoxville, TN and received an A.A. in history in 1998. He continued to the University of Tennessee, Knoxville and received a B.A. in geography in 2001.

Matthew is currently pursuing his masters of science in urban and regional planning with a concentration of transportation planning from the University of Tennessee, Knoxville.